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Assessment of Impacts of Repealing the Universal Helmet Law in South Carolina

Nancy Khanal Chhetri
Clemson University, nchhetr@g.clemson.edu

ASSESSMENT OF IMPACTS OF REPEALING THE UNIVERSAL HELMET LAW
IN SOUTH CAROLINA

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Nancy Khanal Chhetri
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Accepted by:
Dr. Jennifer H. Ogle, Committee
Chair Dr. Wayne A. Sarasua
Dr. Bradley J. Putman

ABSTRACT

The National Highway Traffic Safety Administration (NHTSA) statistics shows that South Carolina is one of the state with the highest number of the motorcycle fatalities and the fatal crashes. South Carolina repealed its Universal Helmet Law in 1980 which might be one of the reason for the increment of crashes and fatalities in South Carolina. Head and facial injuries are main causes of death in case of motorcycle fatal crashes. Helmet use can save number of lives and reduce the head and facial injuries. The thesis focuses on the advantages of the helmet use and necessity of Universal Helmet Law in South Carolina.

The crash data for South Carolina from 1975 to 2015 was collected from Fatality Analysis Reporting System (FARS) to identify the various factors affecting the likelihood of the helmet using the logistic regression. The socio-economic data for South Carolina from 2002 to 2012 was collected from US Census Bureau. The motorcycle crash data from 2002 to 2015 was obtained from the SCDOT database. The roadways for South Carolina was obtained from the RIMS database. The CPI (cost price index) data from Department of Labor's Bureau of Labor's Statistics and fatal crash data was used to identify the effectiveness of helmet use in South Carolina. The social media and newsfeed were collected from twitter and various news channel and word cloud was created to characterize the opponents and ad vocative's viewpoint.

The results show that helmet use before the repeal of the Universal helmet law is three times more than after the repeal of the Universal helmet law. Also, the fatality trend from 1975 to 1980 is decreasing whereas the trend is increasing from 1981 to 2015. Among the various factors age, alcohol consumption and Universal helmet law are the significant factors in determining the likelihood of helmet use in South Carolina using the logistic regression. Universal Helmet Law is one of the major factor in determining the likelihood of helmet use. The total motorcycle crash data of South Carolina from 2013 to 2015 shows that the unhelmeted motorcyclists are twice the helmeted motorcyclists in the total motorcycle crashes. The percentage of helmeted motorcyclist with blood alcohol level >0.08 is five times less than the percentage of the unhelmeted motorcyclists. People with the higher college degree education are more likely to wear the helmet than the people with diploma. Higher household income motorcycle riders are more likely to wear the helmet than the motorcycle riders of lower household income are. Also, the freeways, minor arterial and local roads are more prone to the motorcycle crashes. Highways like Kings Highway, Cleo Chapman Highway and other highways that passes through the urban areas are more prone to the motorcycle crashes. Local roads around the Columbia city and the Greenville city have more chances of having the higher motorcycle crashes. The KDE and Kriging analysis shows that the hot spots vary with and without the normalization of crashes by population. Charleston, which

is a hotspot without normalizing the crashes, changes to be cold spot when the crashes are normalized with the population of that area. The text analysis in the study shows that the opponents focus on having freedom of choosing their own safety. The proponents are more concerned about the public safety, which they support with the facts and researches.

The reinstatement of Universal helmet law in South Carolina is particularly recommended. Various educational programs should be conducted to educate the people regarding the use and effectiveness of helmet. Enforcement should be done in the Highways and local roads that are prone to motorcycle crashes.

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CHAPTER 1. INTRODUCTION

1.1 Background information

Motorcycle registration has grown up in the past ten years with the increase of 46 percent(Highway Statistics, 2016).The increasing motorcycle registration has been accompanied by the increasing motorcycle accidents, property loss, injuries, and fatalities. According to the National Highway Traffic Safety Administration (NHTSA, 2015), in 2015 motorcycle fatalities have increased by 8.3 percent from the year 2012 which is the largest number from 2012. Therefore, with the increasing number of motorcycle registration, it is necessary to have a concern towards the motorcycle safety area.

Motorcycles constitute of 3.23 percent of a total number of motor vehicles in the United States in 2015. There were altogether 8,600,936 motorcycles registered in the United States in 2015 from which the number of motorcycles registered in South Carolina was 116,241 (Statista, The Statistics Porta,2015l). From 1975 to 2015 in United States, the total number of motorcycles involved in the fatal crashes has increased from 3265 to 5076. The total number of motorcycle fatalities from 1975 through 2015 is 157,789. In 2014, the total number of motorcycle fatalities constituted of 14 percent of all motor vehicle fatalities and were more than double the fatalities in 1997 as shown in figure 1-1

(IIHS,2015). The motorcycle fatalities in United States have increased by more than 5 percent in 2015 from the year 1975 (NHTSA, 2015). The proportion of motorcycle fatalities has increased from 5 percent in 1995 to 13 percent in 2015 as shown in Figure 1-2 (IIHS, 2015). There is an increase of 8.3 percent with 4597 number of motorcycle fatalities in 2014 to 4976 number of motorcycle fatalities in 2015. (NHTSA, 2015) Statistics shows that most of the motorcycle fatalities occurred in the 14 states: California, Florida, Georgia, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Taxes, Arizona, Illinois, Michigan and Tennessee. Also, the data for 2014 depicts that South Carolina falls under top 14 states with the higher number of motorcycle fatalities (NHTSA, 2014). In 2013 the statistics showed that there were 13 states along with South Carolina with more motorcycle casualties: Arizona, California, Florida, Illinois, Georgia, Michigan, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Taxes, Indiana (NHTSA, 2013). These statistics shows that South Carolina has been one of those states with high number of motorcycle crashes. Generally, if compared with passenger cars, motorcyclists are more susceptible to be involved in fatal accidents.

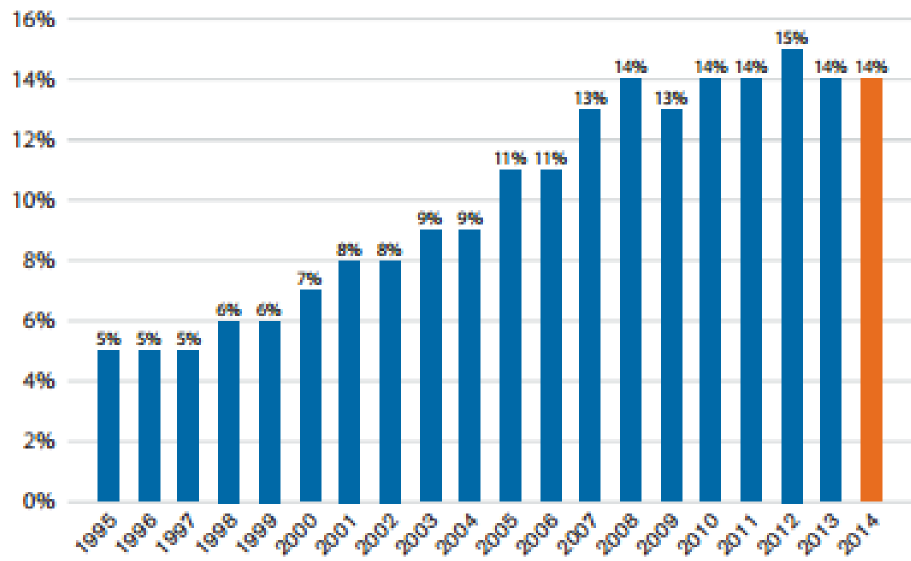


Figure 1-1: Motorcyclist Deaths as a Percent of Total Motor Vehicle Deaths, 1995-2014 (Data Source: Fars)

Figure 1-2: Fatalities by person type (Fars data from 1995 and 2015)

Motorcycle use became very popular in United States after the WWII in 1940s and 1950s. With the increasing motorcycles, there was increase in the number of accidents. The accidents had increased by 20% for the next four years and there was 200 percent increase in the medical costs for the non-helmeted motorcyclists. So, in1966 the National Highway Safety Act was passed to reduce the fatalities. The act also granted the funds to develop the programs. BY 1975, all the states implemented the universal helmet law except for California. Slowly, the opponents started claiming about the infringement of the Constitutional rights. On December 14, 1975, the NHSA was repealed but the federal funds were withheld from the states unwilling to accept the law. Therefore, the National Highway fatality and Injury reduction act was introduced on May 1989, which has proposed to, withheld 10 percent of Federal highway aid from the states refusing the law. But the bill was passed withholding only 3 percent of the federal highway fund. In 1995, the national motorcycle lobby successfully lobbied to repeal the 3 percent of the highway safety fund penalty. And many states started repealing their universal helmet law in 1997.

In United States, there are two types of motorcycle helmet laws known as Universal Helmet law and Partial Helmet Law. The Universal Helmet Law requires all the motorcycle riders to wear the helmet whereas the Partial Helmet Law only requires only the motorcyclist below the age 17, 18 or 20 to wear the helmets. Currently 19 states and District of Columbia have Universal helmet law.

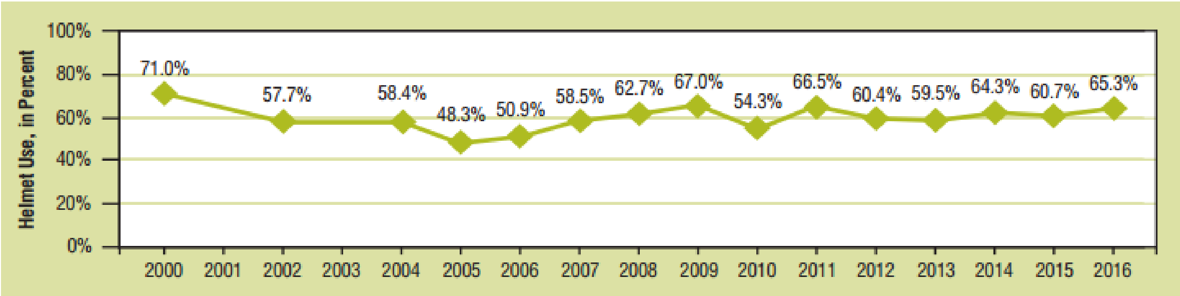
It has been noticed that there is a huge drop down of 5.7 percentage in the usage of helmet since the year 2000 as shown in Figure 1-3 (NHTSA, 2016). In 2016, the helmet use was higher in the states with Universal helmet laws with close to 100 percent but which all the helmets were not complaint than in the other states with partial or no helmet laws with 53.5 percent as shown in Figure 1-4(NHTSA, 2016)

Head injuries are the major cause of deaths in motorcycle crashes, which shows that it is necessary to use the helmets properly. Cook et al., (NHTSA 2009) identified that the motorcyclists with helmets are less likely to get the head and facial injuries than compared with Non-helmeted motorcyclists. Helmet use can reduce the likelihood of fatal crashes by 37 percent and 63 percent for the injuries (NHTSA, 2004). Helmeted motorcyclists were less likely to experience the dreadful brain injuries.

NHTSA (2008c) indicated that after the reinstatement of Universal Helmet Law in Louisiana, the fatalities were decreased by 30 percent. The injuries were lower after the reinstatement of law compared to before the law. Louisiana had the first decline in motorcycle fatalities in its first six years.

On July 1, 2000, Florida repealed its Universal Helmet Law to Partial Helmet Law. Florida experienced the increase in motorcycle fatalities in the beginning of the 6 months of the repeal of helmet law. The number of fatalities after the following two years were 71 percent greater than the two years before the law (NHTSA, 2005).

South Carolina has a Non Universal helmet law which requires all the motorcyclist below the age of 20 to wear the helmets. South Carolina adopted the Universal Helmet Law in the year 1967 which required the mandatory use of helmets by all the motorcyclists but it changed its law to Non - Universal helmet law in the year 1980 requiring only the motorcyclist below 20 year of age to wear the helmet.



*From 1994-2004, motorcycle helmet use data was collected every other year. Motorcycle helmet use data was not collected in 2001 and 2003.

Figure 1-3: Motorcycle Helmet Use, 2000-2016 (Source: NOPUS)

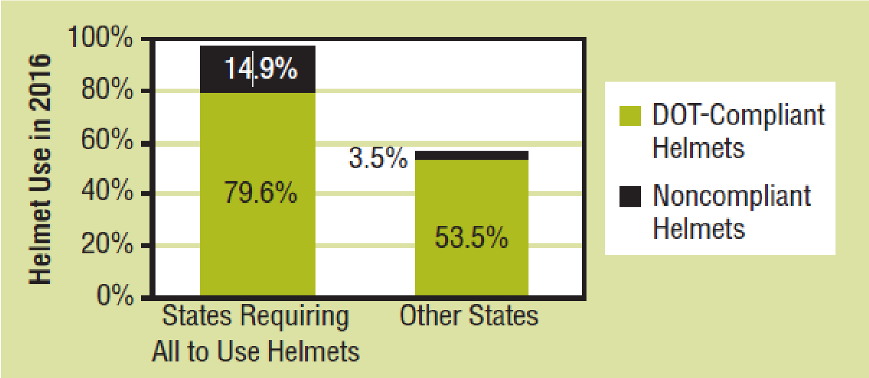


Figure1-4: Motorcycle Helmet Use in 2016, by State law and Helmet Type (Source: NOPUS)

1.2 Problem statement:

The Statistics from 1975 through 2015 shows that the Motorcycle crashes have been a big issue in United States as it constitutes 14 percent of the motor vehicle fatal crashes even though it represents only 3 percent of the total motor vehicles. South Carolina has been listed in those 10 states to have the higher number of the motorcycle crashes since the past few years. South Carolina has second highest motorcycle fatality rate in the nation after Wyoming. A total of 140 motorcyclists were killed in South Carolina in2015 which is 14.3 % of all the occupants killed that year. Over all 74% of the motorcycle riders killed in South Carolina in crashes in 2015 were not wearing helmet. Currently South Carolina has the partial helmet law, and is one of the two South Eastern states without the universal helmet law. Many types of researches have been done for different states regarding the changes in motorcycle helmet law and its effect on the motorcycle fatal crashes and helmet usage but none has been done related to South Carolina.

1.3 Objectives of the study

The objective of this study is to evaluate the impact after the repeal of universal helmet law on motorcycle crashes and fatalities in South Carolina. Also, the study identifies the behavioral/Socio-economic/ Geographic factors to be addressed. The research also characterizes the opponent and advocate viewpoints on universal helmet laws to enable the development of persuasive educational materials.

1.4 Organization of Thesis

The thesis is divided into five chapters. Chapter one represents the introduction which includes the background, problems and objective of the study. Chapter two represents the Literature review which presents the research works that have been done before related to the motorcycle crashes, related factors, and helmet law. Chapter three discusses the sources of data, data collection process, the methodology used in the analyzing the data. Chapter four discusses and presents the results of the analysis. Chapter five includes the conclusion and recommendations based on the results of the analysis.

CHAPTER 2. LITERATURE REVIEW

2.1. Introduction

A detailed literature review was conducted to identify the trends of motor vehicles and motor cycle crashes, helmet laws, factors affecting the usage of helmets, estimation of the economic and life saved by the helmets, motorcycle crashes geocoding, hot spot analysis of the motorcycle crashes and various methodologies that have been used for the traffic safety. It mainly focuses on the importance of helmet on decreasing the motorcycle fatalities and the fatal crashes. Various Safety methods have been used for decreasing the motorcycle fatalities and fatal crashes but the difficult task might be choosing the right one for the required output.

2.2. Trends in Fatality of Motorcycles and Motor Vehicles

The increasing number of population has resulted in a very high change in the registration of the motor vehicles. The total number of the vehicles registered in 2015 was 260,350,938 with an increase of 88.7 % from the year 1975. The motorcycles constitute of 3.23 % of the total number of motor vehicles (Highway Statistics, 2016). The motorcyclist fatality rate per 100,000 registered motorcyles in 2015 was 57.85 whereas the passenger car fatlity rate per 100,000 registered passenger cars was 9.48 which shows that the motorcyclists fatality rate was five times the passenger cars fatality rate (NHTSA, 2015).

The total number of motorcyclists killed in 2015 is 4976 which is an increase of 8 percent from the year 2014 (IIHS, 2015) whereas the total number of occupants killed in passenger cars in 2015 was 12,628 which is an increase of 5.6 percent from the year 2014 (NHTSA, 2015). The motorcycle fatalities constitutes of 13 percent of all the motor vehicle crash deaths (IIHS, 2015). The motorcycle fatalities is increasing along with the increase in the motorcycle registration. It also shows that the rate of motorcycle fatalities is very high in comparision with the passenger cars as shown in Figure 2-1.

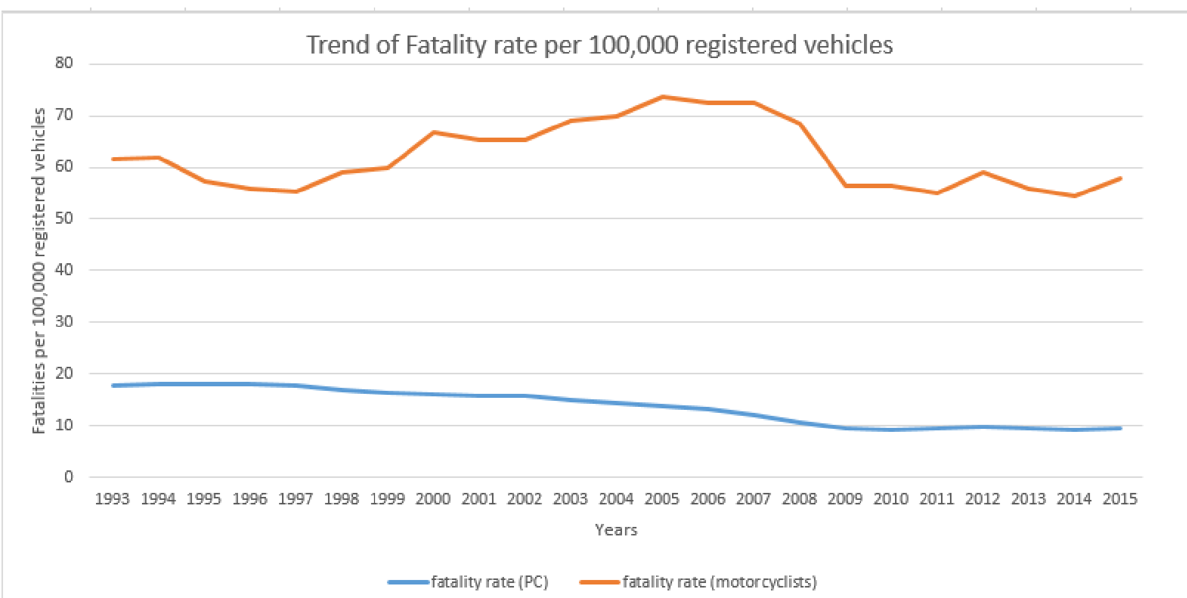


Figure 2-1: Fatality rate per 100,000 registered vehicles for passenger cars and motorcycles

The fatality rate per 100,000 registered vehicles in United States for the year 2015 was 12.47 and the fatality rate per 100,000 population was 10.92. The fatalities rate per 100,000 registered vehicles for South Carolina was 23.47 which is the highest among all the states and the fatality rate per 100,000 population was 19.95(NHTSA, 2015). The fatalities in South Carolina has increased by 19 percent in 2015 from the year 1975. The motorcycle fatalities in South Carolina has been increasing for the past few years. The number of the motorcyclist killed in South Carolina for 2015 is 184 which has been increased from the year 2014 which was 121. (NHTSA, 2015).

From 2000 to 2008 the motorcycle fatalities have increased by 83 % and the motorcycle registrations have increased by 78% (NHTSA, 2009). But the motorcycle Vehicle Miles of Travel (VMT) have increased by 38%. (Desai et al.,2008).

The study conducted by Dan Middleton et al., (2014) sought to determine the appropriate sites for the motorcycle counts which was conducted in four states (Texas, Michigan, Wisconsin and Montana). The Author evaluated the relationship between the motorcycle crash locations and potential count sites. The study showed that the spatial distribution of the motorcycle crashes is related to the spatial distribution of the traffic. The study also found that the weekend motorcycle crash locations can be used to determine the weekend count sites and same for the weekdays.

The study conducted by Sarasua et al., (2010) showed that the current traffic detection systems used for estimating the VMT do not detect and classify the motorcycles properly because of their small size, narrow width, low metal mass and single wheel track.

The research conducted by Lyon et al., (2016) showed that in the absence of the accurate motorcycle counts for the AADT, the total AADT can be used. FHWA requires states to report state-level motorcycle VMT data which was optional before 2007.If the states are elected to report the motorcycle VMT data, they would often calculate the measure as a standard proportion of the total VMT. (FHWA, 2008)

International Overview:

Peden et al. (2004) highlighted that road traffic injuries account to significant deaths all around the world with 20-50 million injured annually. Low and medium income countries constitute of most of the deaths as motorcycles are the popular means of transportation in such countries (WHO, 2006). The study done in Taiwan (Chang & Yeh, 2006) shows that the motorcyclists in Taiwan ride the motorcycles without driving education or training.

The motorcyclists face many motorcycle crashes as they often share the traffic space with fast-moving, heavier and bigger cars, buses and trucks, and because they are less visible. In addition, their lack of physical protection makes their passengers vulnerable to being injured if they are involved in a collision (WHO, 2006).

In case of Latin America and Caribbean countries, over half of the road traffic deaths occur among pedestrians, motorcyclists and bicyclists. A stronger traffic law enforcement is required to decrease the number of road deaths and protect the vulnerable groups. The Pedestrians deaths consists of 27%, motorcyclists as 20% and bicyclists as 3.7%. The Dominican Republic Country has the highest number of the motorcycle accidents which is 63 % (WHO, 2006)

2.3. Helmet Usage, Helmet Usage Laws and Their Effectiveness

Going through the analysis of data from 1975 through 2015 (NHTSA, 2015), it seems that the motorcycle riders are at more risk than occupants of passenger cars. Per registered vehicles the motorcycle fatality rate in 2015 was six times more than the passenger car fatality rate. Also per vehicle miles of travel in 2015 the motorcycle fatality rate was 29 times more than the fatality rate of passenger cars (NHTSA, 2015).

Lawrence J.Cook and Tim Kerns, (NHTSA, 2008) found out the relationship between the motorcycle helmet use and the motorcyles crashes, injuries, hospital charges, etc. They pointed out that the helmeted motorcyclists are less likely to suffer from the head and facial injuries than the unhelmeted motorcyclists. The unhelmeted motorcyclists are more susceptible to the Traumatic brain injuries (TBIs).They showed that 15 percent of the hospitalized helmeted motorcyclists had TBIs than 21 percent of the hospitalized non helmeted motorcyclists.

The usage of helmet saved around 1664 lives in United States in 2014. Also additional lives of 660 could have been saved if the helmet usage percentage was 100 percent.(National Center for Statistics and Analysis, 2016). The helmet usage can reduce the likelihood of fatal crashes by 37 percent and the injuries by 41 percent (NHTSA, 1988). Pickerell and Starnes, (2008) estimated that an unhelmeted motorcyclist is likey to have a fatal injury by 40 percent and a non fatal injury by 15 percent than an Non-helmeted motorcyclists. In United States, different states have different helmet use laws.

- Universal helmet use law: This law requires mandatory use of helmets by all the ages of motorcyclists.
- Non-Universal helmet use law: This law requires the motorcyclist of age below 17, 18 or 20 to wear the helmets.
- No helmet use law: There is no mandatory use of helmets for such law.

South Carolina has a Non-Universal helmet law, which requires the entire motorcyclist below the age of 20 to wear the helmets. South Carolina adopted the Universal Helmet Law in the year 1967 which required the mandatory use of helmets by all the motorcyclists but it changed its law to Non - Universal helmet law in the year 1980 requiring only the motorcyclist below 20 year of age to wear the helmet (IIHS, 2015). Currently 19 states and the District of Columbia have laws requiring all the motorcyclist to wear the helmet which is the Universal Helmet law. There are 28 states, which requires the motorcyclist below certain year of age to wear the helmet. There are three states (Illinois, Iowa and New Hampshire) which do not have any helmet law (IIHS, 2015). The figure 2- below shows the maps of states with different Helmet Laws.

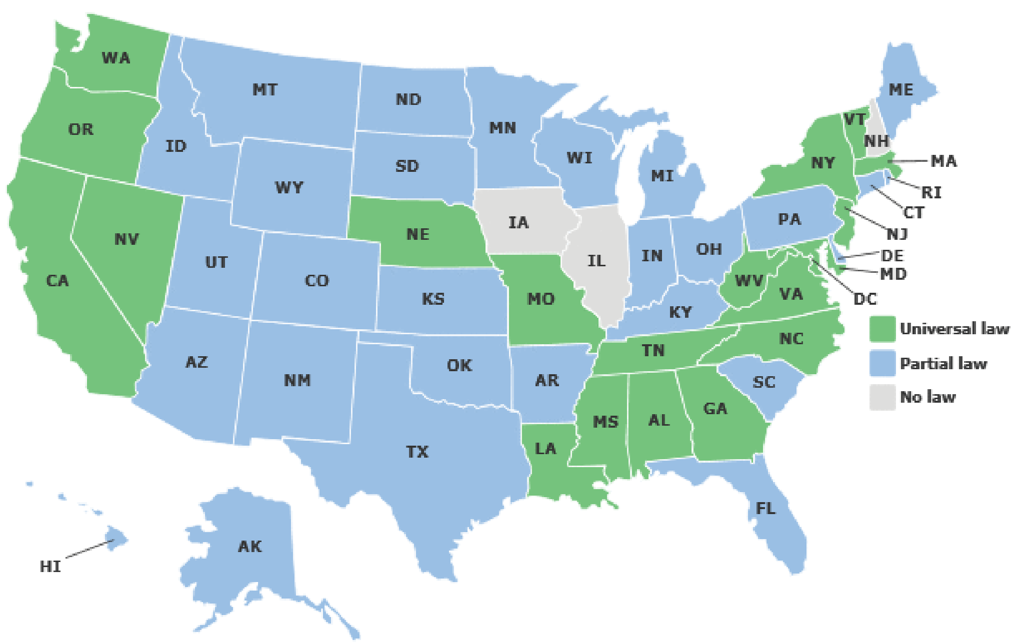


Figure 2-2: Maps of the states with helmet laws in United States by 2015

William et al. (1979) represented that if the helmet wear is mandatory for all the motorcyclists almost the usage percentage is 100 percent. There is less usage of helmets when it is not compulsory for all the riders to wear the helmets. Therefore, the Partial helmet law decreases the helmet usage rate in the motorcyclists. Overall helmet use rate is higher in the states where there is the partial helmet law as compared to other states where there is partial or no helmet laws.

The survey conducted by (NHTSA, 2015) shows that the states having the Universal Helmet Law had the higher percentage of helmet usage compared to the state with Non- Universal Helmet Laws.

The report of NHTSA indicated that Louisiana has amended the motorcycle helmet laws several times; in August 2004, Louisiana reinstated its universal helmet law, which require the entire motorcyclist rider to wear the helmets. Multiple logistic regression showed a strong positive effect on usage of helmets. The odds of wearing the helmet after the reinstated law were 11.7 times greater compared to the odds of wearing the helmet before the law. It also showed that the injuries were lower after the law was reinstated compared to before the law. Fatalities were decreased by 30 percent during the post law period than the pre law period. The fatal crashes were also decreased after the reintroduction of the law. The report illustrated that Louisiana has the first decline in the motorcycle fatalities in its first six years (NHTSA, 2008c).

Florida repealed its Universal helmet law to Partial helmet law on July 1, 2000, which require the riders below the age of 17 to wear the helmets. Florida experienced the increase in motorcycle fatalities in the beginning of the 6 months of the repeal of helmet law. The number of fatalities after the following two years were 71 percent greater than the two years before the law (NHTSA, 2005).

International overview

Head and neck injury are the main reason of deaths for the motorcyclist. Head injuries accounts up to 75 percent of the death in European countries while it accounts up to 88 percent of deaths in case of low and middle income countries (Umar, 2002).

Proper Use of helmets can reduce the fatalities and head injuries . The Effective enforcement of helmet laws can reduce the motorcycle crashes and increase the usage rate of helmet (WHO, 2006). Among all only 169 countries have established the national law out of which only 74 countries have the law of wearing the helmets correctly. There are some countries where it is only compulsory to wear the helmet in the speeding areas or certain criteria. Only 70 countries have the comprehensive helmet law that applies to all the drivers and passengers. The study in nine low and middle-income countries showed that half of the helmets being worn were non-standard helmets. In total 44 countries have the proper helmet law, which includes all the users with a requirement for fastening the helmet and has applied the helmet standard as shown in figure 2-3. In 46 countries, a minimum age is specified for the children to ride as passengers ranging from 3 to 14 years old, like Australia, Vietnam and Malaysia (WHO, 2006). But few countries like Afghanistan, Dominica, Fiji, and Somalia do not have any national helmet law although they have high number of motorcycle crashes (WHO, 2006)

The study conducted by WHO (2006) regarding the helmet law, enforcements and the helmet standards on different countries of the world also shows that many countries lack the data regarding the motorcycles. So, there are no sufficient researches regarding motorcycle for various countries due to the lack of proper data.

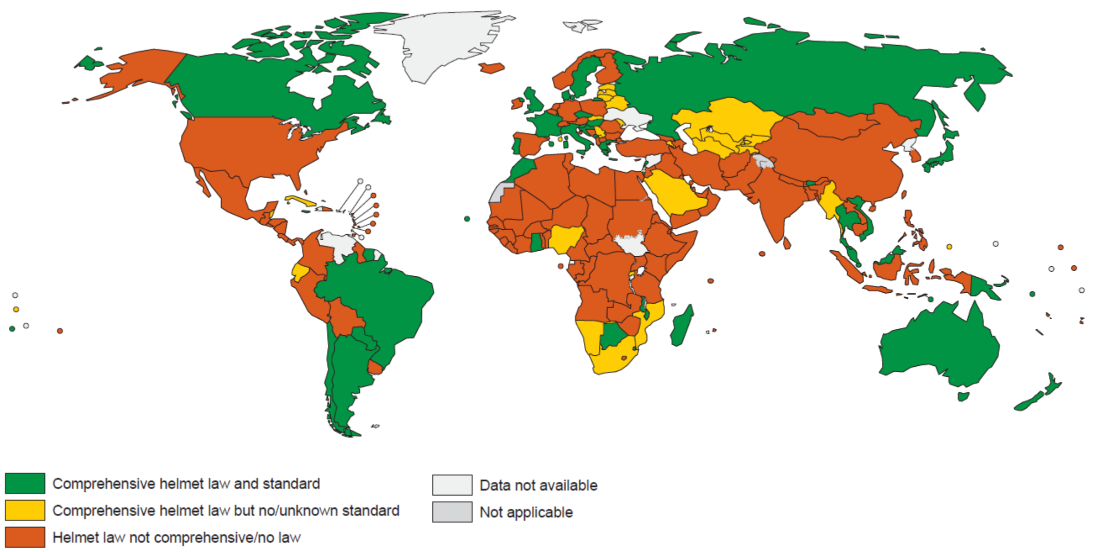


Figure2-3: Motorcycle helmet laws and helmet standards, by country/area

2.4. Estimation of Lives and Costs Saved by the Helmet Use

NHTSA (NCSA, 2016) estimated that in 2014, 1669 lives and 660 additional lives were saved and $3 billion in economic costs and $18 billion in comprehensive costs were saved using motorcycle helmet in United States. The estimates are calculated using the effectiveness of motorcycle helmets as 37 percent for the operators and 41 percent for the passengers. The estimates for injury are also calculated using the effectiveness as 8 percent for the minor and 13 percent for the serious injury. NHTSA used the helmeted motorcyclist fatalities to determine the number of lives saved and the additional lives saved are estimated by using the unhelmeted motorcyclist fatalities. The costs are estimated using the Department of Labor's Consumer Price Index (CPI) with the base year as 2010.

Blincoe et al., (2015) estimated in United States the total cost of motor cycle crashes in 2010 as $12.9 billion and $66 billion in societal harm as comprehensive costs which also includes the societal costs using the effectiveness of helmets and number of helmeted and unhelmeted fatalities. They estimated the helmeted and unhelmeted incidence separately and then different cases for each incidence were identified. They used the cost per fatality to derive the estimates of the economic impact of helmet use and non-use from 1975 through 2010.

Deutermann, W. (2005) estimated that 1158 lives were saved for the year 2003 and additional 640 motorcyclists could have been saved if the helmet usage rate were 100 percent. He used the helmet effectiveness of 37 percent based on the data of Fatality Analysis Reporting System (FARS).

By using the same method as above, NHTSA (2011) estimated that the number of motorcyclists saved in 2008 were 1829 and an additional of 822 lives could have been saved had all motorcyclists' worn helmets. The economic cost saving was found out to be approximately $2.9 billion in 2008 and an additional of $1.3 billion could have been saved if all the motorcyclists had worn the helmets

2.5. Other Factors Affecting the Motorcycle Fatal Crashes and Helmet Usage

Previous studies showed that many other factors may contribute to the motorcycle fatalities. Motorcycle fatal crashes and helmet usage are affected by various factors like age, gender, helmet laws, alcohol use, time of day, month of the year etc.

2.5.1. Gender

The study conducted by Pickrell and Timonthy (NHTSA, 2008) indicated that in both single vehicle and multi vehicle motorcycle crashes 97 % of the fatalities were male motorcycle riders. In both types of crashes female motorcycle riders were more helmeted than the male motorcycle riders. The survey done by NHTSA depicted that the female motorcycle fatalities have increased from 5 to 10 percent in 2015 in Alabama.

2.5.2. Alcohol usage

Several factors have been associated with the high motorcycle fatalities and alcohol usage is one of them. The percentage of motorcycle riders in fatal crashes were higher which had the blood alcohol level of at least 0.08 grams per deciliter (NHTSA, 2009). Motorcycle riders with blood alcohol level 0.00 g/dl had the higher helmet use than other groups (NHTSA, 2008).

2.5.3. Age

Pickrell and Timonthy (NHTSA, 2008) highlighted that the motorcycle rider from age group 20-29 and over age 59 had the highest helmet use whereas the motorcycle riders for age group 40-49 had the lowest helmet use. The highest motorcycle rider fatalities were from the age group 20-29. The 2015 survey (NHTSA, 2015) indicates that Florida experienced most of the motorcyclists in age group 35-34 and 55-64. The average age of the motorcycle fatalities was 47 in 2015 than which was 30 in 1995.

2.5.4. Land use

The survey conducted by NHTSA shows that there is an increase in the motorcycle fatalities in the urban areas. Urban crashes rose from 30 fatalities in 2014 to 44 fatalities in 2015 (NHTSA, 2015). This shows that the motorcycle riders are increasing in the urban areas.

2.5.5. Speeding

It has been seen that the speeding is another factor that influences the motorcycle fatal crashes. 36 percent of the motorcyclists in fatal crashes were due to speeding which is higher than in other motor vehicle crashes. (NHTSA, 2008a)

2.5.6. Time of day

Time of the day is also an important factor which affects the helmet usage rate and the motorcycle fatalities. The survey (NHTSA, 2008) shows that the helmet usage rate is higher during the day (6 a.m. to 6 p.m.) than during the night (6 p.m. to 6 a.m.). There were more motorcycle fatalities during the night time than during the day for single vehicle crashes but the case was reverse for the multi-vehicle crashes.

2.5.7. Income

Mostly it is seen that the there is more use of motorcycles in the low and medium income countries. At the same time the number of the motorcycle crashes are also higher in case of such countries. (WHO, 2006). The research conducted by Imran Khan et al., (2008) indicated that the higher personal income motorcyclists were more likely to wear the helmets than the low-income motorcyclists.

2.5.8. Education level

The study conducted by Imran Khan et al., (2008) in Karachi, Pakistan showed that the users who were better educated or have a graduate degree were 2.3 times more likely to wear the helmet than the uneducated ones. Also the educated users were more likely to have positive attitude towards wearing a helmet than the uneducated ones.

2.6. Modelling of Factors Associated with Motorcycle Crashes and Helmet Usage

The study by Pickrell and Timonthy (2008) reported the likelihood of helmet usage by the age above 21 involved in the crashes. They used the logistic regression method to estimate the odds of using the helmets by the motorcycle rider. The report separated the crashes into Single vehicle motorcycle crashes and two- vehicle crashes, which involved one motorcycle and another passenger vehicle. The authors used the logistic regression model to conclude that the odds of a rider wearing a helmet in a single vehicle motorcycle crashes are 72 percent less in the state without the Universal Helmet law compared to the states with Universal Helmet Law. In case of two- vehicle crashes the odds ratio of wearing the helmet in states with Universal Helmet Law to the states without the Universal Helmet Law is 0.69. The analysis reveals that the most important factor for determining the usage of helmet in fatal crashes is the status of the motorcycle helmet law in different states.

The study conducted by Liu and Dissanayake (2009) analyzed the factors affecting the severity of crashes on the gravel roads. The authors developed the logistic regression models to estimate the likelihood of injury crashes of various severity levels using thirty different factors. Several variables like equipment usage, alcohol involvement, speed limit etc. were found significant in the process of analysis. The odds ratio gave the importance of each factors on causing the injury crashes separately.

The study conducted by NHTSA (2008c) evaluated the motorcycle helmet usage rate, fatalities and injuries after the reinstatement Universal Helmet Law in Louisiana in August 2004. The logistic regression analysis indicated the positive relation between the helmet usage and the reinstatement of the Universal Helmet Law. The model showed that the odds of wearing the helmet after the reinstatement of the law were 11.7 times greater than comparing the helmet usage before the law. The analysis also showed that the injuries were lower in the post law period than the pre-law period. The fatalities were also decreased by thirty percent during the post law period than the pre-law period.

The study by Emmanuel Geofrey Mwakapasa (2011) analyzed the relation between the attitude of the commercial motorcyclist towards wearing the helmet and the practice of the helmet usage. The logistic regression analysis showed that the commercial motorcyclists had positive attitude towards wearing the helmet. The helmet usage rate is mostly related to having the positive attitude towards the helmet and the level of education. The author also indicated that the there was a vast difference of wearing the helmets between the riders and the passengers. The motorcycle riders were more likely to wear the helmets than the passengers were.

The study by Indupuru (2010) evaluated the relationship of the number of motorcycle fatal crashes and the various factors involved. The author used the logistic regression method to show that the fatal crashes increased with the increase in speeding, use of alcohol, when the motorcyclist is less than 25 years of age. The study also estimated that there is increase in the fatal crashes when there are accidents on the horizontal curves, major roadways and graded segments and when the motorcycle rider has no helmet. The study also indicates that the enactment of Universal Helmet Law in Ohio is necessary.

Hung et al., (2008) conducted the study in Vietnam to identify the factors associated with the use of motorcycle helmet use. The authors used the logistic regression method to create the model and found out that the Universal helmet legislation, positive attitude towards the helmet, older age, trips greater than 10km, higher level education were few factors for determining the use of the helmet.

2.7. Spatial Analysis

To develop effective countermeasure and enforcements the accidents should be analyzed spatially in Geographic Information System (GIS). To find out the causes of accidents and improve traffic safety, hot spot (highly accident occurrence area) analyses have an important role. The hot spot analysis can be done by using one of the spatial analyst tool, which is also called the Kernel Density Estimation (KDE).

The study conducted in Hawaii, Honolulu by Kim et al., (2007) regarding motorcycling and alcohol impaired motorcycling used logistic regression and spatial clustering .The authors found out that the behavioral and temporal factors are very significant among other factors.

The study conducted by A Rukewe et al., (2014) in Nigeria regarding the variation of crash frequency by type showed that the motorbikes have the highest clustering than other types. The author used the GIS software, Anova test and T test for the analysis.

The study conducted by Kelvin et al., (2007) in United states regarding the motorcycle related crashes showed that the four curved roadways were found in the vicinity of the crashes. The author used the geocoded crash data and ortho images for the analysis.

De Andrade, Luciano et al. (2014) made a study in Brazil regarding the road traffic injuries (RTI) using the spatial analysis tool called kernel density estimator to identify the main hot spots. They identified that higher incidence of crashes occurred on sections of highway with double lanes and both the eastern and western regions had higher crashes than compared to the central regions.

Kweku et al., (2015) conducted the study regarding the identification of the socio- economic and demographic characteristics of the at-risk drivers (drivers involved in the crashes) residential areas in South Carolina. The authors prepared the risk map based on the spatial analysis tool and the statistical analysis identified that the median house hold income areas had more risk of having at-risk drivers than other areas. The study also found out that the young age drivers are more involved in crashes than the other age group.

Erdogan et al. (2008) made a study to analyze the accident hotspots and determine the safety lacking areas in the city of Afyron, Turkey. The author conducted the KDE analysis to analyze accident hot spots. The analysis showed that almost same locations were hot spots, which were located junction points, cross roads and access roads to the villages and towns. The study also indicated that the weekends had the higher frequencies of crashes than other days.

W.Kilamanu et al., (2011) made a study to identify the patterns of single and multi-vehicle crashes in Western Australia between 1999 to 2008 using the kernel density estimation method. The analysis showed that the Perth is the major hot spot area with more than 80 percent of the total crashes in Western Australia.

study conducted by Kim et al. (2007) in Hawaii regarding the motorcycling and alcohol-impaired motorcycling using the logistic regression model and spatial cluster analysis showed that behavioral and temporal factors are more significant in determining the alcohol impaired crash pattern than environmental factors.

The study conducted by Adika et al. (2015) conducted a study regarding assessment of crash location improvement in Map based geocoding system. Various GIS analytical tools like buffer analysis and proximity analysis were used to find the accuracy of the crash locations. The author analyzed that in 2010 most of the crash locations were outside the crash boundary while 2010 and 2012 data showed that most of the crash locations were within the travel way. The study also showed that the spatial analysis tool with the proper crash data helped in determining the dangerous driveways.

Yalcin et al., (2015) conducted a study regarding spatial analysis of motorbikes and bicycles crashes in Osmaniye in Turkey. They used the kernel density estimation method to find out the hotspots in the area of the Osmaniye. They found that the most of the two wheeled vehicles accidents were on the main transportation roads especially at the intersections with the high traffic density streets. They concluded that when the traffic flow rate is fast there is more chances of having the two wheeled vehicles accidents.

Famili et al., (2017) conducted the study in Mashhad, Iran to identify the pattern of accidents in urban traffic. The authors used the traditional Kernel

Density Estimation method (KDE) and the SANET for analyzing three types of accidents (fatal, injury, PDO). The analysis showed that the more traffic accidents are within the core of the urban areas and the traffic accidents decreases with the distance from the urban areas.

Anderson (2009) conducted a study on methodology of using Geographic Information System (GIS) and Kernel Density Estimation to determine the accidents hot spots in London, UK. The author estimated the map showing the hot spots using the Kernel Density Estimation and later the environmental variables are added to the hotspot cells which gives the outcomes of the similar hotspots by using K-means clustering.

Reardon, Joseph M., et al. (2017) conducted a study regarding the hotspots of road traffic injuries in Moshi, Tanzania. The study analyzed the areas with the higher number of collisions. The study concluded that the most of the injuries happened at the four intersections on two main roads. One of the road consists of the high speed one lane road and the other road refers to the high population density with more traffic.

Banos and Huguenin Richard (2000) made a map showing the distribution of child pedestrian accidents using the Kernel Density Estimation (KDE) in the city of Lille, France. The authors used the KDE methods (Kernel density estimation, clusters) to map the distribution of accidents and to select sites which deserve further investigations. Later the logistic modelling was used to evaluate the influence of the proximity of schools on the distribution of child pedestrian road accidents.

The study conducted by Graittinger et al., (2005) prepared the thematic map of the Tuscaloosa County by using the GIS analysis feature called buffering to select the crashes that occurred within the certain road features. The analysis helped in identifying the roadway feature that may contribute to the maximum crash occurrences as shown in figure 2-4. The authors also showed various kinds of crashes

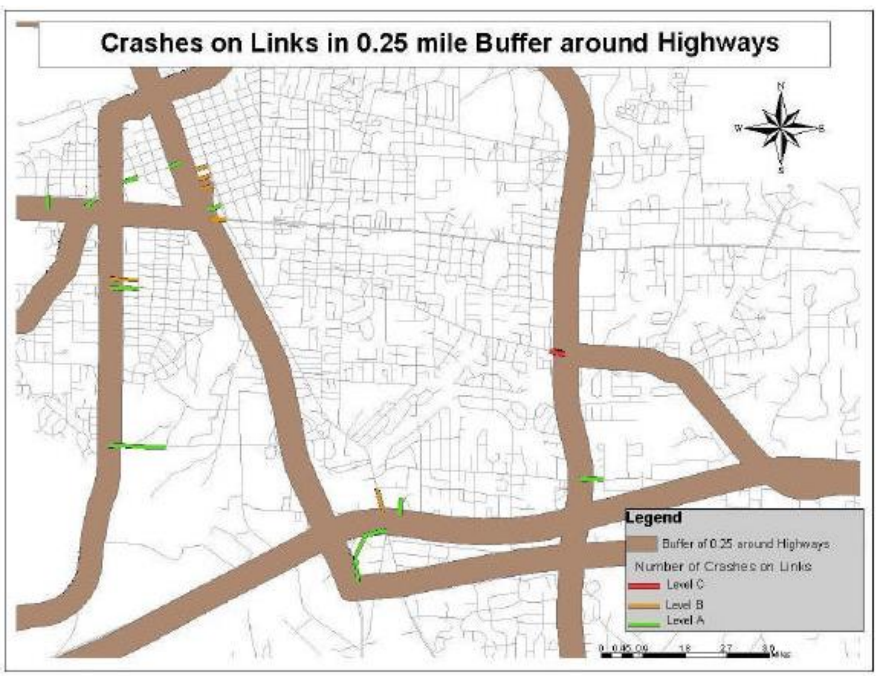


Figure 2-4: Crashes on road segment within 0.25 buffer around highways

The study conducted by Kweku et al. (2016) conducted the safety analysis of spatial phenomena regarding the residences of drivers involved in the crashes using various spatial analysis tool. The study showed that the areas with high household income and high educational attainment were more likely to have less chances of the drivers involved in the fatal and injury crashes than other area. The author used the proximity analysis to show that the probability of involving in the fatal or injury crashes is less for the trips that is near to the home.

Payman Salamati et al., (2015) conducted the study in Tehran to identify the high crash areas that result in the injuries and deaths from November 2011 through February 2012. The authors used the ArcMap to extract the coordinates of the injuries locations and then used the overlay tool to overlap the different layers of geographical data. The study resulted that more deaths were in the west and northwest areas of Tehran and most of the deaths and injuries involved the motorcycles.

2.8. Literature Review Summary

As discussed above the trends of the fatal crashes and the fatalities for motor vehicles and motorcycles shows that more safety measures are required for the motorcyclists than the motor vehicle occupants. The fatalities and fatal crashes for the motorcyclists is increasing per year than the fatalities and fatal crashes for the motor vehicle occupants both in United States and South Carolina. Various researches have proved helmet usage as one of main safety measure to decrease the motorcycle crashes. Status of the State Helmet Law is also one of the important factor in determining the helmet usage rate, fatality rate and the fatal crashes. Trend analysis, estimation of lives and cost saved by helmets and logistic regression are the important methods that can be used to show the importance of Universal Helmet Law as a major factor in decreasing the fatalities and fatal crashes and increasing the usage of the helmet. The overview of the motorcycle fatal crashes and helmet use laws in various countries gives the way towards transferring the ideas, knowledge and systems prevailing in United States to different parts of the world.

CHAPTER 3. METHODOLOGY

Various methods were used to complete the different objectives. The following table shows the objectives with its methods used during the analysis.

Table 3-1: The objectives and the methods used for the analysis

Objectives	Methods
1. Evaluate the impacts after the repeal of Universal Helmet Law on motorcycles crashes, injuries and fatalities in South Carolina	1. Fatality trends, Fatal crash trends, Helmet use trends, Frequency charts 2. Cost- Benefit Analysis
2. Identify the Behavioral/ Socio-demographic/ Socio-economic/ Geographic factors associated with motorcycle crashes in South Carolina	3. Logistic Regression 4. Spatial Join 5. Buffer Analysis 6. Kernel Density Estimation 7. Kriging Methods
3. Characterize the opponent/ advocate viewpoints on Universal Helmet Laws to enable the development of persuasive educational materials.	8. Text Analysis

3.1. Data collection

The data for the thesis were collected from various sources. Table 2 shows the matrix that matches the data sources with various methods.

Table 3-2: Mapping the data sources with the analysis methods

Data sources	Analysis methods					
	Trends	Frequency tables	Benefit-Cost	Logistic Regression	Spatial Analysis	Text Analysis
FARS (1975-2015)	●	●	●	●		
US Census Bureau			●		●	
Social media/Online news feed						●
Driver's License Data					●	
SCDOT crash data (2007-2015)					●	
RIMS (Roadway Inventory)					●	

3.1.1. FARS

One of the source is Fatality Analysis Reporting System (FARS). FARS is the nationwide census that provides yearly data regarding the fatal injuries that occurred during the motor vehicle crashes to the National Highway Traffic Safety Administration (NHTSA) and the American Public. FARS provides an overall measure of the highway safety, helps provide the solutions and evaluates different Highway Safety Programs and motor vehicle safety standards. FARS manages the raw data for each year in the excel format. Crash data for twenty years from 1975 through 2015 for the state of South Carolina were downloaded as a dbf file from FARS website (www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars). FARS data are in relational format which is categorized into three files for each year. Those three files are Accident records, Person records and Vehicle records. Each of these files contain a common variable known an ST_CASE that can be linked to the same cases or records of the three files. The ST_CASE data element is the unique case number assigned to each crash.

3.1.1.1. Merging Files

The files were joined to each other using the Join tool in GIS (Geographic Information System). The accident table file contains all the information related to the accident like name of state, location of the crash, time and day, date, lighting condition, number of fatalities etc. The Persons table file contains one record for each person that is involved in the accident. The Persons table file consist of information like age, gender, restraint use etc. The Person table file were joined with the related Accident file through the same variable, ST_CASE.

The Vehicle table file contains one record for each vehicle that is involved in the accident. The Vehicle table file contains information like vehicle type, vehicle number etc. The vehicle table file is joined with the other two files through the common variable, ST_CASE.

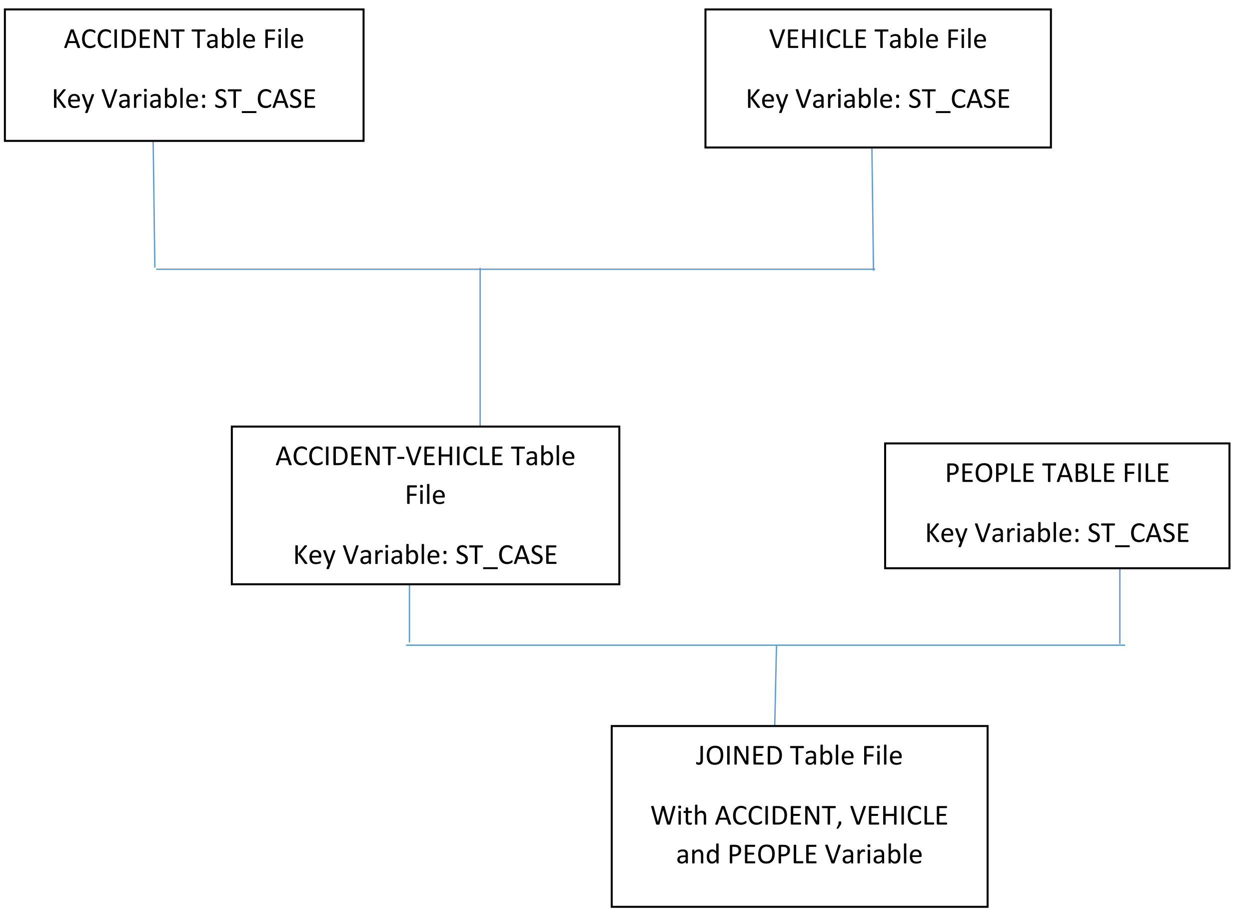


Figure 3-1: A flow chart showing a process of joining the three table files of FARS into one file with the common variable.

3.1.1.2. Query and Sorting the Data

The next step after joining the vehicle and the person files properly to the accident files was to make a new file with only motorcycles data. For this "select by attribute" tool in GIS software was used.

"Select by attribute" tool can be used to select the features using an attribute query. This tool allows providing a query expression that can be used to select features that match the selection criteria. This tool helped in querying and sorting the data by creating a new data table file. The total number of motorcycle fatal crashes in South Carolina for each year was found out by using the variables "ACCIDENT_STATE and VEHICLE_BODY_TYPE". The number of rows provided the total number of fatal crashes.

The total number of fatalities were found out by taking the total sum of the column named as "FATAL". For the helmet usage, the total number of helmeted and non-helmeted fatalities were found out using the variables "PERSON_MAN_REST" from the year 1975 till 1990 and "PERSON_REST_USE" from the year 1990 till 2015.These selected records were later extracted to the excel file from the GIS software. The variables used to identify the motorcycle fatal crashes based on gender, age group, alcohol consumption and time of day were PERSON_SEX, PERSON_AGE, DR_DRUNK AND LGT_COND.

3.1.2. RIMS (Roadway Inventory Monitoring System)

This is another source used in the study for the data collection process. RIMS is the geospatial based system which is responsible for managing all the aspects of DOT's roadway inventory. RIMS manage the data like route type, number of lanes, AADT, functional class, street networks. The files for the roadway of South Carolina for the spatial analysis is obtained from this system.

3.1.2.1. Merging the files

The files were joined using the join tool in ArcGIS. The crash files consist of 3 records. The Location records has all the information regarding the location, time, date etc. about the crash. The occupant record consists of information regarding the person involved in the crash. The Unit records consist of information regarding the vehicles involved in the crash. The three records are joined to each other using the same variable "ANO" which represents the accident number. The motorcycle crashes are extracted from the total crash by using the variable "Unit_UTC" which represents the body type of the vehicle. The resulting motorcycle crashes of various years are joined with the help of merge tool in the GIS to give the final output merged crash data of motorcycles from 2010 to 2015.

3.1.3. Department of Labor's Bureau of Labor Statistics

The Bureau of Labor Statistics of the U.S Department is the principal federal agency responsible for measuring labor market activity, working conditions and price changes in the economy. Its mission is to collect, analyze and provide the essential economic information to support the public and private decision-making. The cost price index for cost-benefit analysis for each year from 1975 through 2015 was obtained from the website of Department of Labor's Bureau of Labor Statistics which is https://data.bls.gov/cgi-bin/surveymost?cu.

3.1.4. US Census Bureau

The US census bureau provides the TIGER/line shapefiles and related database files of selected geographic information. TIGER represents the topologically integrated geographic encoding and referencing database. County subdivisions are the primary divisions of counties and their equivalent entities for the reporting of Census Bureau data. The shapefile for the South Carolina borders with county subdivisions are obtained from this website https://catalog.data.gov/dataset/tiger-line-shapefile-2013-state-south-carolina-current-county-subdivision-state-based. The US census bureau also provides the state-wise socio-economic data like total population, education level, income level with the limited set of the TIGER/ line shapefiles for 2010.

3.1.5. SCDOT and SCDMV

The residential locations of riders who contributed to fatal and injury crashes (at-risk drivers) from 2007 to 2012 were compiled using a combination of the South Carolina Department of Transportation (SCDOT) crash database and the South Carolina Department of Motor Vehicles (SCDMV) driver's license database for the socio-economic analysis. (Brown et al.,2016)

The total motorcycle crash data from 2013 to 2015 were also obtained from South Carolina Department of Transportation (SCDOT) crash database for the Behavioral/Socio-demographic analysis.

The total motorcycle crash data from 2011 to 2015 were obtained from the South Carolina Department of Transportation (SCDOT) crash database for the hot spot analysis.

3.1.6. Social Media

Various sources from social media like Facebook, tweeter, news channels were used in the study for characterizing the opponent/ advocative viewpoints on universal helmet laws.

3.2. Fatality and Helmet use trends, Frequency tables and Percentages

3.2.1. Trend Analysis

This part in Methodology shows the trend line of the motorcycle fatal crashes and fatalities for two different time periods (1975 to 1980 and 1981 to 2015) with the Universal Helmet Law from 1975 to 1980 and without the Universal Helmet Law from 1981 to 2015. Also, the trend line for the helmet usage for two different time period was found out. A trend line represents a trend, the long-term movement in time series data. It tells whether a data set have increased or decreased over the period of time. A more proper position and slope of the trend line can be calculated by using statistical techniques like linear regression. Trend lines typically are straight lines, although some variations use higher degree polynomials depending on the degree of curvature desired in the line. A linear regression line method was used in Excel to find the best fit of the data. A regression line is based upon the best fitting curve.

$Y= a + bX$ where a is the y-intercept and b is the slope of the line.

Linear regression is a method for modeling the relationship between a scalar dependent variable Y and one or more independent variables denoted by X. A simple linear regression models the relationship between two variables by fitting a linear equation to observed data. Linear regression figures out the best-fitting straight line through the points. The best-fitting line is called a regression line as shown in Figure 3-7. In the above graph the red dots represents the observed data, the green line represents the deviations from the blue line which represents the linear regression line.

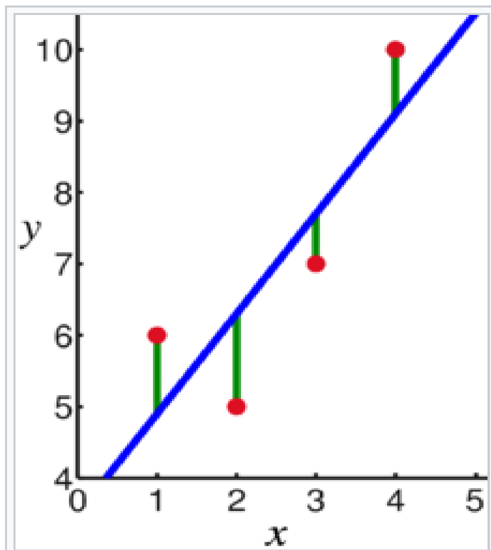


Figure 3-2: Simple Linear Regression Line Example (source: Wikipedia)

3.5.2. Frequency table and percentages

In statistics, a frequency distribution is a table that displays the frequency of various outcomes in a sample. Each entry in the table contains the frequency or count of the occurrences of values within a particular group or interval, and in this way, the table summarizes the distribution of values in the sample.

In my study, the frequency table of different variables have been identified. The frequency table of helmeted and unhelmet fatal crashes for various factors like gender, age group, day and night, DUI and DWI are found out from 1975 through 2015 and for the whole combined years.

The Variables used to determine the frequencies and percentages for the total motorcycle crash data are:

- Age
- Alcohol Consumption (for fatal crash only)
- Gender
- Severity level
- Average speed
- Race

3.3. Cost-Benefit Analysis

The annual estimates of lives and costs saved using motorcycle helmets are obtained by using the effectiveness of the motorcycle helmets in preventing the deaths and injuries. Helmet effectiveness role as 37 percent for the fatalities which is 37 percent of the lives can be saved for riders and 41 percent for the passengers. The number of motorcycle fatalities gives the estimation of the motorcyclists saved by helmets and the associated costs. By using the helmet effectiveness, the number of lives that were saved as they wore a helmet can be estimated. Also by using the effectiveness of helmet the injuries that were controlled and which could have been controlled by wearing the helmet can be evaluated. The base year for economic estimates should for the inflation factor. The inflation rate of each year can be found out from Department of Labor's Bureau of Labor Statistics. The number of lives that were saved by motorcycle helmet by using the number of helmeted fatalities. For motorcycle, fatal crashes, the helmet effectiveness of 0.37. The potential fatalities are estimated as:

$$\text{fatalities}_{\text{potential}} = \text{fatalities}_{\text{Helmeted}} / (1-0.37)$$

The number of lives saved by the helmets is given by the total number of potential fatalities less the actual number of fatalities.

$$\text{Number of fatalities saved by the helmets} = \text{fatalities}_{\text{potential}} - \text{fatalities}_{\text{actual}}$$

The additional lives that could be saved if all motorcyclists had worn helmets are as:

$$\text{Operator fatalities}_{\text{unhelmeted}} * \text{Effectiveness}_{\text{role for operators}}$$

The total amount of costs saved can be calculated by multiplying the number of motorcyclists who were prevented from being killed. The cost bases can be found out from "The Economic and Societal Impact of Motor Vehicle Crashes, 2015". The required inflation factor is obtained using data from the Department of Labor's Bureau of Labor Statistics (http://data.bls.gov/cgi-bin/surveymost?cu). The inflation rate can be found out by dividing the value of Annual for the required year by the base year. The economic cost per fatality for the base year is multiplied by the inflation rate to estimate the economic cost per fatality for the required year.

Economic cost per fatality for the required year = economic cost per fatality for the base year * inflation rate

Economic cost saving = Economic cost per fatality *total number of lives saved by the helmets

The economic cost savings for fatalities that could have been prevented by 100 percent helmet use = Economic cost per fatality for the required year * additional lives that could have been saved

3.4. Logistic Regression

Various factors were analyzed during the study to perform the logistic regression analysis.

3.4.1. Description of Variables Selected for Logistic Regression

FARS data was used for the analysis. It analyses the following factors as they relate to motorcycle helmet use in fatal crashes. Each factor is listed in the appropriate categories within that factor.

- Dependent Variables: “Usage of Helmet” is a dependent variable in the analysis. This variable was recorded as a binary variable with (1) as fatal crashes with helmets on and (0) as fatal crashes without the helmets.
- Independent Variables: The chosen independent variables for the analysis are shown below. All the variables were recorded with a number (1) or (0).

I. Gender: This factor talks about the gender of the motorcyclist who got involved in the crash.

   a. Female
   b. Male (Reference group)

II. Age group: This factor shows the age group of the motorcyclist involved in the crash. The reference group was taken as less than 20

   a. Less than 20 (reference group)
   b. 20-29
   c. 30-39
   d. 40-49
   e. 50-59

f. Greater than 59

III. Time of day: This factor represents the time of the day at which the crash has occurred. The reference is the day group.

a. Day: 6 a.m. to 6 p. m (Reference group)

b. Night: 6 p. m to 6 a. m

IV. Alcohol Consumption: This factor indicates whether the motorcyclist was under DUI or DWI when the crash occurred. The group with DWI is taken as the reference group.

V. Helmet Law: This variable indicates that during which helmet law the crash occurred. Non-Universal Helmet Law was taken as the reference group.

a. Universal Helmet Law

b. Non-Universal Helmet Law

3.4.2. Description of Logistic Regression

The logistic regression model was used in the research to predict the probability of wearing a helmet by the motorcyclist in the fatal crash. Logistic regression represents the relation between the variable with the categorical response and the independent variable. It can deal with the categorical responses which come during the study and investigates its relationship with the independent variables. So, for these kinds of study logistic regression is more preferred. The logistic regression does not assume the linear relation between the dependent and independent variables but it assumes the linear regression relation between the log of the dependent variable and the independent variable.

Since it is a binary response model, so the helmet usage can take two possible values. It can be denoted as 1 or 0 with 1 if the motorcyclist wears the helmet and 0 if the motorcyclist does not wear the helmet. The linear logistic model has the form:

Log it (π) = log (π/ 1-π) = $\beta_o + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots + \beta_k X_k$

π= 1/ (1+e^$^{-(\beta_o + \beta_1 X)}$)

Where,

β_o= the intercept,

β = regression coefficients for covariates X

X = independent variables

π = the response probability to be modeled

Applying the logistic regression to the probability is generally referred to as taking the logit. The natural log of the odds ratio is called the logit. The odds ratio is a ratio of two odds. The odds are related to the probability but expressed in a different way. The odds are the probability of the event occurring to the probability of the same event not occurring. For a probability of success π, the odds of success can be shown as,

$$\text{Odds} = \pi / (1 - \pi)$$

If the odds is greater than 1 then the probability of success is greater than failure. If the odds is less than 1 then the probability failure is greater than the success. In our study, the odds ratio compares the two groups of each variable. If we take an example of gender, the odds ratio compares the odds of the male group with the odds of a female group of gender variable. (Indupuru, 2010)

$$\text{Odds ratio} = (\pi_1 / (1 - \pi_1)) / ((\pi_2 / (1 - \pi_2))$$

Probability of helmet usage	Male	Female
Probability of wearing a helmet (success)	π_1	π_2
Probability of not wearing a helmet (Failure)	$(1-\pi_1)$	$(1-\pi_2)$

The odds ratio greater than 1 indicates that the male group is more likely to wear helmets than the female group. The odds ratio less than 1 indicates that the female group is more likely to wear helmets than the female group.

"R" software was used for the study to carry out the logistic regression analysis. The software also analyses the variable as if the variable is found greater than α=0.05 level than the variable is treated as insignificant in affecting the dependent variable. The software also creates the odds ratio based on the reference group to find the magnitude of each variable.

3.5. Spatial Join

The socio-economic data and the blocks for the spatial join analysis was obtained from US census bureau and the motorcycle crash data (2002-2012) obtained from South Carolina Department of Transportation. Driver information was aggregated to census block groups and one square mile grids for macro and micro level analysis respectively. To aid in identifying subpopulations within the state with the greatest potential for safety program impacts, socioeconomic and demographic data for the block groups was obtained from the 2010 Census data for South Carolina and compiled with the at-risk driver data. (Brown et al.,2016).

Residential Nine-Digit Zip Code Data for Drivers Contributing to Crashes

To research the socioeconomic characteristics of motorcycle riders who contributed to fatal and injury crashes (at-risk riders) in South Carolina, motorcycle rider's residential locations at a fine geographic scale had to be acquired. South Carolina crash data includes a vehicle file that identifies all the motorcycle riders involved in crashes by motorcycle riders' license number. A list of riders' license numbers of riders involved in crashes from 2007 to 2012 was extracted from the vehicle file obtained from the SCDOT and provided to the SCDMV to procure the residential locations of riders. (Brown et al.,2016)

The resolution of 9-digit riders residence zip code data is finer than the respective census block group data that was obtained with associated socio-economic data. The resultant encrypted list of 9-digit zip codes provided by the SCDMV was decoded and preprocessed. To create a unique relationship between a rider and a crash, relational database joins were created between the

SCDOT crash database files and the driver 9-digit zip codes acquired from the SCDMV in Microsoft Access. This combined dataset captured at-risk drivers that were involved in more than one crash within the given year and/or across years. (Brown et al.,2016)

The socio-economic variables used for the analysis:

I. Income: The variable indicates that if the income of the people has effect on the occurrence of the motorcycle crashes.

II. Education: The analysis of this variable shows that if the number of education in the certain area has any relation with the number of motorcycle crashes on that area.

Census Block Group Boundaries and Associated Socioeconomic Data

Census data is aggregated at different levels of geography. Block group is the smallest level of aggregation that includes data with detailed demographic and socioeconomic information. There are, on average, 39 blocks in a block group, and there is usually a cluster of block groups in a census tract (www.census.gov). The level of aggregation that was chosen for this analysis was the census block group because of the available socioeconomic and demographic attributes at that level of geography. To perform block group analysis, Census block group GIS shape files containing 3,054 block groups for South Carolina were obtained from the US Census Bureau. Demographic and socio-economic data by block group was retrieved from the Census Bureau and the National Historical Geographic Information System (NHGIS) and joined with the census block group shapefile. Each block group is assigned to either Helmeted (greater than 50%) and or unhelmeted (less than 50%) category as shown in figure 3-3. The process for the block categories is shown in figure 3-4.

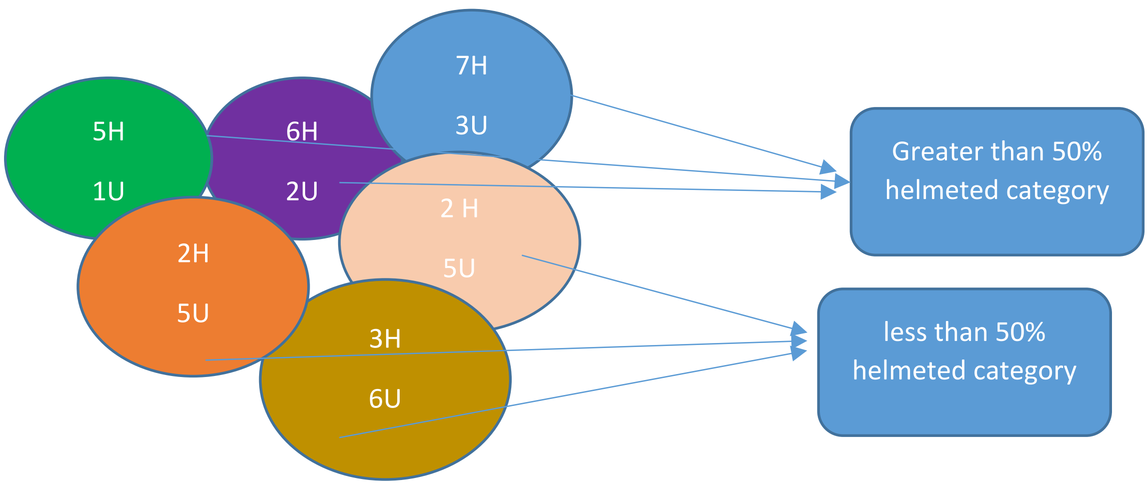


Figure 3-3: Assigning the blocks to either greater than 50% helmeted category or less than 50% helmeted category

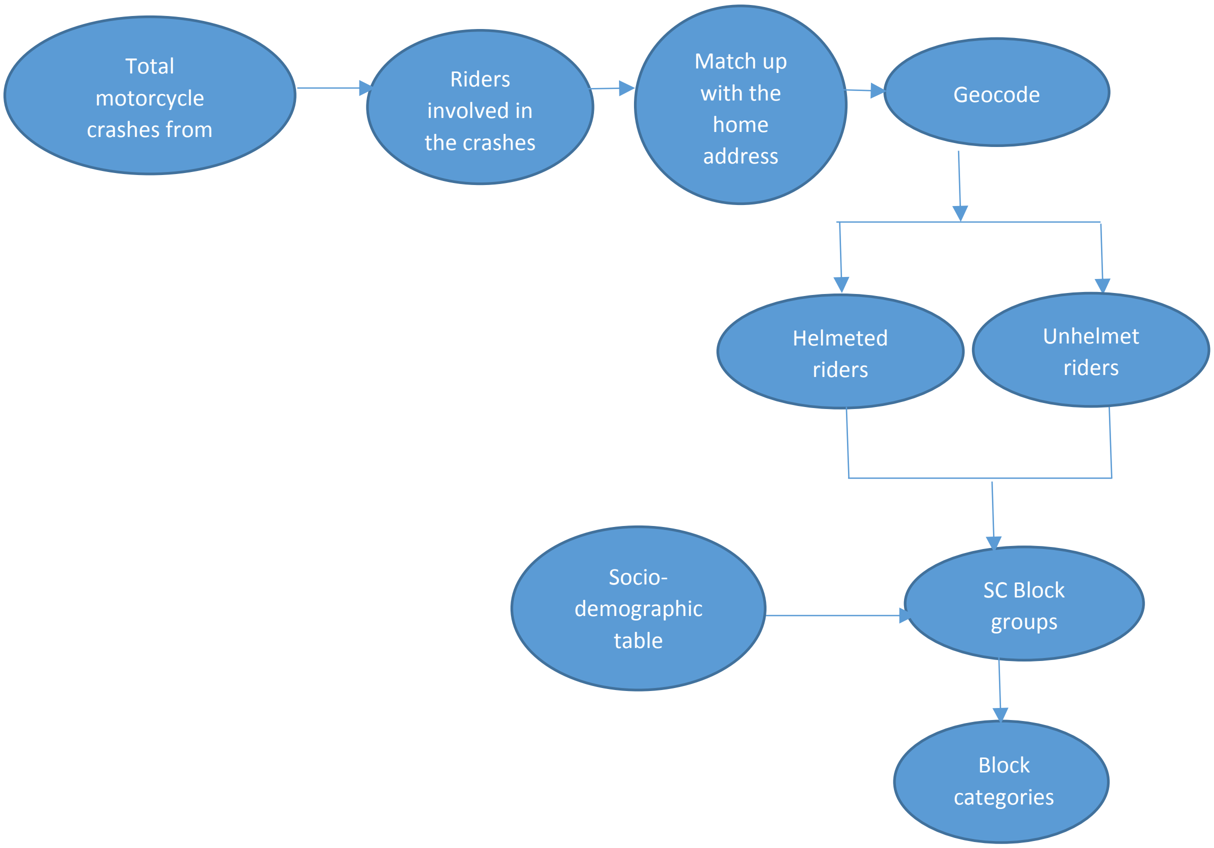


Figure 3-4: Process for the block category analysis

3.6. Buffer Analysis

Spatial analysis is the location based analysis which includes the topological, geometric or geographic properties. There are various applications in the GIS software through which we can perform the spatial analysis. The GIS analysis feature contains a tool called Buffer. In the buffer tool there is an important parameter called Method which determines how the buffer are constructed. The buffer tool creates an offset distance on both sides of the line segment as shown in the figure 3-5. The buffer operation creates a zone of specific width around a point, line or a polygon. The buffer tool creates new feature class of buffer polygon around the specified input feature.

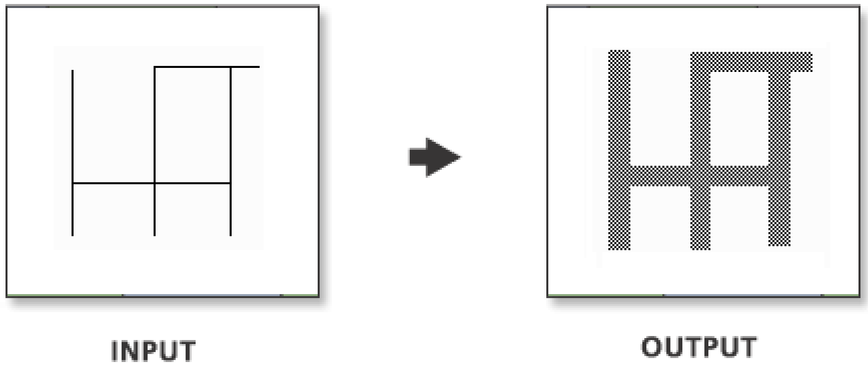


Figure 3-5: Buffer of a line feature class using 20 feet distance
(source: http://desktop.arcgis.com/en/arcmap/10.3/tools/analysis-toolbox/buffer.htm)

In our study the buffer tool was used with the offset distance of 30 feet to create a new buffered polygon feature class from the roadway shape files which was obtained from the RIMS data base as shown in figure 3-6. The merged crash files (2010 -2015) were then joined to the buffered feature class using spatial join tool as shown in figure 3-7. The spatial join tool joins the data of one feature layer to the other feature layer. The final joined feature layer is again joined to the RIMS raw roadway file using the spatial tool to create a thematic map based on color which represents the number of crashes and the line weight which represents the functional class of the roadways.

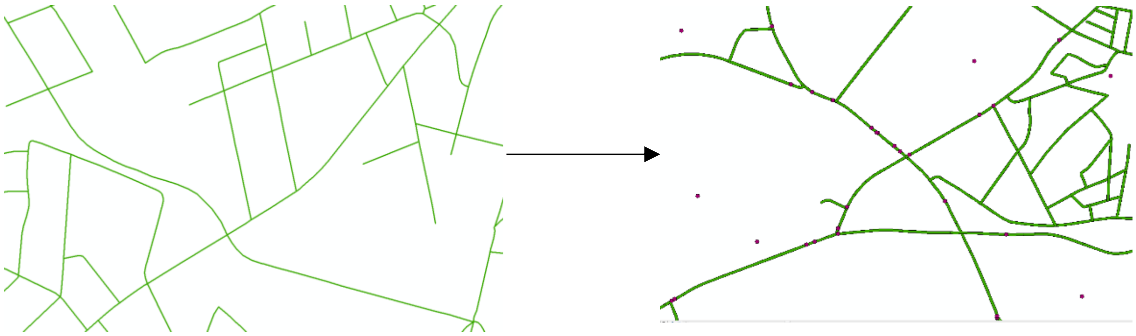


Figure 3-6: Buffer of a roadway using a distance of 30 feet

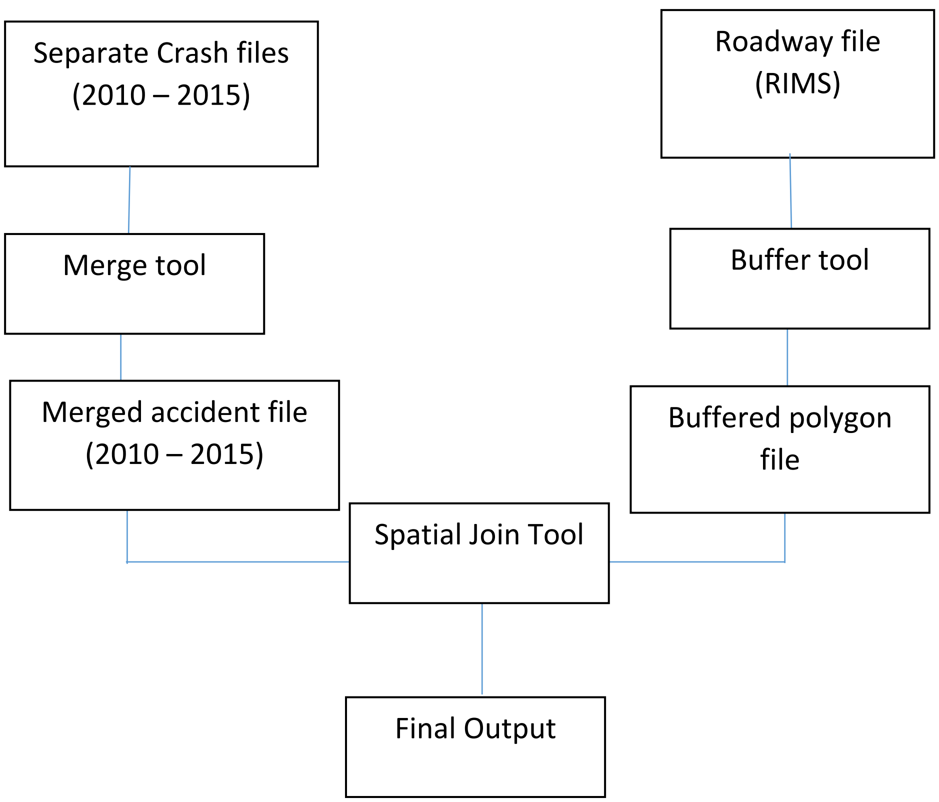


Figure 3-7: Flow chart to show joined output file after using the merge, buffer and join tool

3.7. Kernel Density Estimation

One of the methods to show the hotspots (accident prone areas) of the crashes is by using the Kernel Density Estimation method (KDE) in ArcMap. This is also one of the application of ArcGIS. Density analysis takes known quantities of some phenomenon and spreads them into landscape based on the measured quantity at each location and the spatial relationship of the locations of the measured quantity (Silverman, 1986).

Kernel density calculates the density of features in the neighborhood around those features. Kernel density estimation is an exploratory method to identify the location of clusters at high, local and even densities. It assumes that the event pattern has the density at any location in the very region and not only just to that location where the event occurs. Kernel Density Estimation estimates the event density by counting the number of events in a region. This region is called the Kernel and is centered at the location where the estimation is to be made. Kernel density function is a symmetric function which is centered at zero and having an area of 1. This method can be used for both point and line features. It creates a smooth curve around each point with highest value at the center of the point and decreases with the increasing distance from the point. The total density is calculated by adding the volumes of all the kernel surfaces as shown in figure 3-8 (wicklin, 2016). In our study the crash file for the density estimation is obtained from the FARS data. The fatal crash data is from 1975 to 2015.

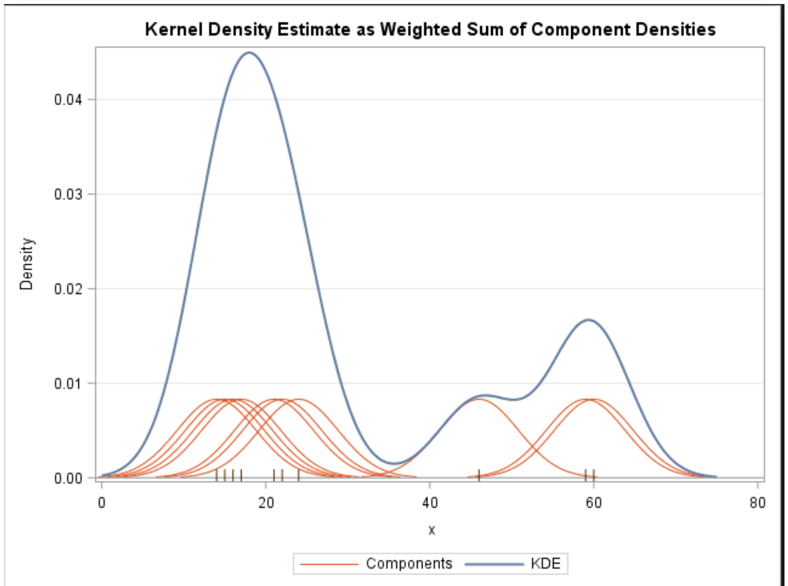


Figure 3-8: Kernel Density Estimate as weighted sum of component densities
(source: http://blogs.sas.com/content/iml/2016/07/27/visualize-kernel-density-estimate.html)

The Kernel density estimator can be represented as:

$F(x) = 1/nb^2 \sum K (d_i/b)$

Where b is the bandwidth, K is function of the Kernel density, d_i is the distance from the center in the bandwidth and n is the number of observations.

3.8. Kriging Analysis

The method to show the hot spots is the Kriging analysis. For this analysis, the total motorcycle crashes from 2010-2015 were used to find the hotspots and which is normalized based on the population. The analysis weighs the surrounding measured values to derive a prediction for an unmeasured location. Kriging is an advanced geostatistical procedure that generates an estimated surface from a scattered set of points with z-values. Unlike other interpolation methods in the Interpolation toolset, to use the Kriging tool effectively involves an interactive investigation of the spatial behavior of the phenomenon represented by the z-values before you select the best estimation method for generating the output surface. *(Source: esri, ArcMap for desktop, 2017)*

The general formula for both interpolators is formed as a weighted sum of the data:

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

Where:

$Z(s_i)$ = the measured value at the ith location

Λ_i = an unknown weight for the measured value at the ith location

S_o= the prediction location

N= the number of measured values

3.9. Text Analysis

In our study the viewpoints of the opponent and advocative are obtained from the various news channels and social media. The word cloud analysis was used during the study. The word or the tag cloud is a visual representation of the text data, which is typically used to identify the keyword in the text. It helps in identifying the key issues, trends and opinions of the people related to the certain topic.

The news was copied from the news channel and the twitter feeds were copied from the twitter. The software "Tag Cloud" was used to make word cloud. The software counts the frequency of the word in the whole sentences and bolds out the words which have the highest number of occurrence. The word cloud was prepared separately for the helmet law advocates and opponents

CHAPTER 4. RESULTS

4.1. Introduction

It has now become a very important matter to give concern towards the motorcycle safety in South Carolina. The results obtained from the research gives the overall idea of motorcycle fatal crashes with and without the Universal Helmet Law in South Carolina.

4.2. Results for fatality, fatal crash and helmet use trends

The total number of motorcycle fatality were decreasing before the repeal of the helmet laws whereas the total number of motorcycle fatality after the repeal of the helmet law is increased.

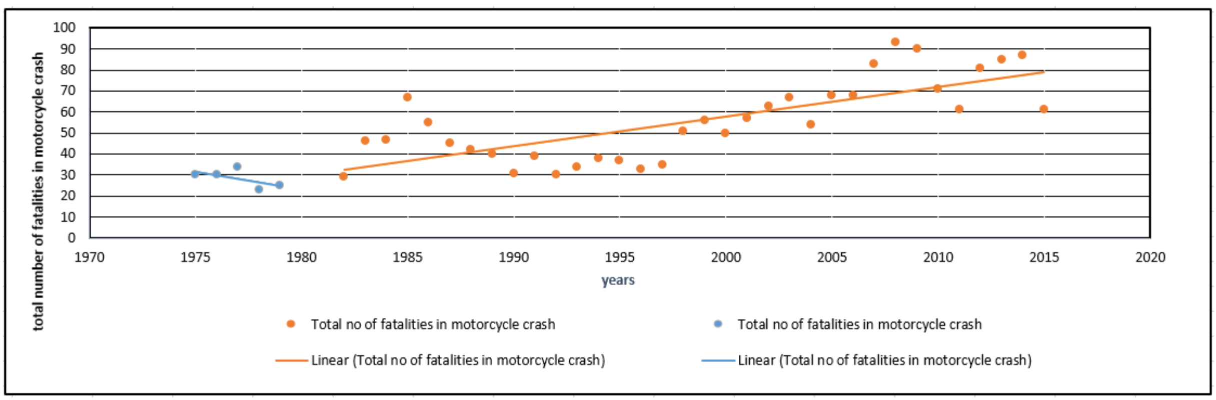


Figure 4-1: Motorcycle fatality trend before and after the repeal of Universal helmet law in South Carolina

As shown in figure 4-2, the percentage of the helmet use in fatal crash before the repeal of the Universal Helmet Law in South Carolina is higher than compared to the helmet use after the repeal of the Universal Helmet Law. As shown in table 4-1 and figure 4-3, the percentage of helmet use before the repeal of Universal Helmet Law is 72.7 whereas the percentage after the repeal of Universal Helmet Law is 20.4

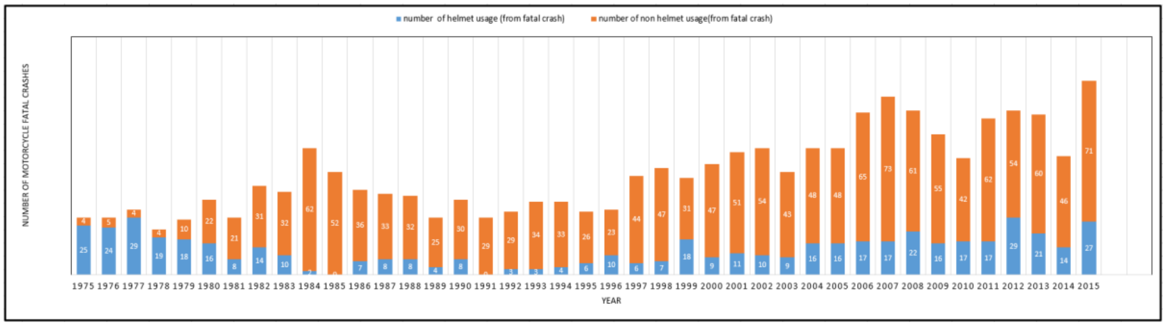


Figure 4-2: Involvement in fatal crashes by helmet use (1975-2015)

Table 4-1: Helmet use statistics for riders in fatal crashes before after the repeal of the Universal helmet law

Years	Total Fatal Crashes	Helmet Use	Percent Helmet Use
1975-1980	180	130	72.70%
1981-2015	1924	394	20.40%

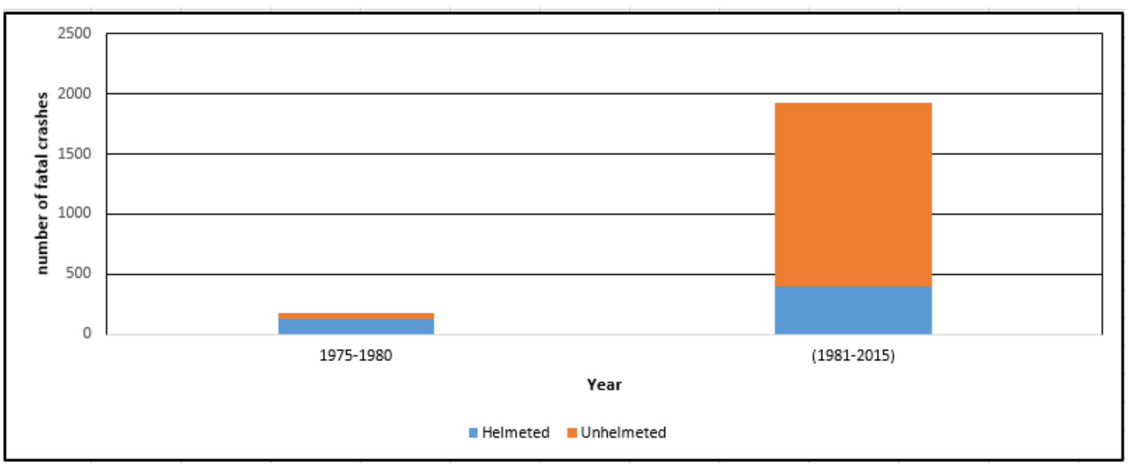


Figure 4-3: Involvement in fatal crash before and after the repeal of Universal Helmet Law by Helmet use

The total fatal crashes involving the male motorcyclists is 2046 whereas the total fatal crashes involving female motorcyclist is only 58. The helmet use by the male per fatal crashes is 32.8 percent whereas the helmet use by the female in the fatal crashes is 38.9 percent as shown in table 4-2. The total number of male motorcyclists is very high than the female motorcyclists so we can say that there are predominantly male motorcyclists than the female motorcyclists as shown in figure 4-4.

Table 4-5: Percent Helmet Use based on Sex (1975-2015)

Sex	Total Fatal Crashes	Helmet use	Percent Helmet Use
Male	2046	506	32.80%
Female	58	16	38.09%

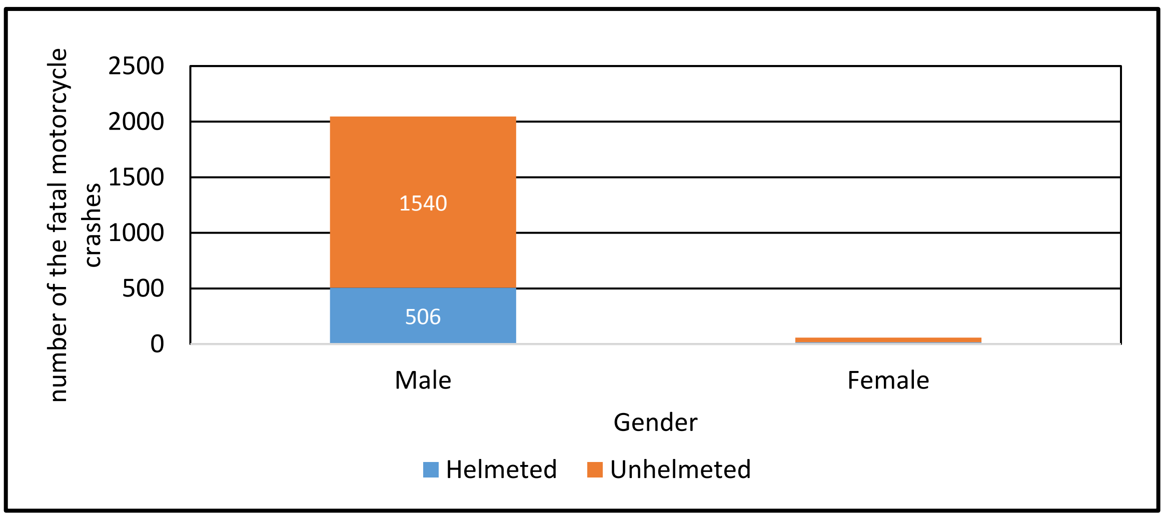


Figure 4-4: Involvement in fatal motorcycle crashes by gender and helmet use (1975-2015)

The Frequency distribution as shown in figure 4-5 indicates that the age group 20-29 are more involved in fatal crashes than other age group. As shown in table 4-6, it also shows that the helmet use by the age group less than 20 in the fatal crashes is 38.8 percent. The helmet use by the age group 20-29 in the fatal crash is 23.5 percent. The fatal crashes involving helmet use for the age group 30-39 is 20.9 percent. For 40-49 age group the helmet use in the fatal crashes is 18.7 percent. For age group 50-59 the helmet use in the fatal crashes is 24.4 percent. For age group above 59 the fatal crashes involving helmet use is 33.05 percent. The total number of fatal crashes is highest for the age group 20-29 with 747 number of fatal crashes.

Table 4-6: Percent of Helmet Use based on different age group (1975-2015)

Age	Total Fatal crashes	Helmet use	Percent Helmet use
Less than 20	188	73	38.83%
20-29	747	176	23.56%
30-39	497	104	20.92%
40-49	362	68	18.78%
50-59	258	63	24.41%
>59	118	39	33.05%

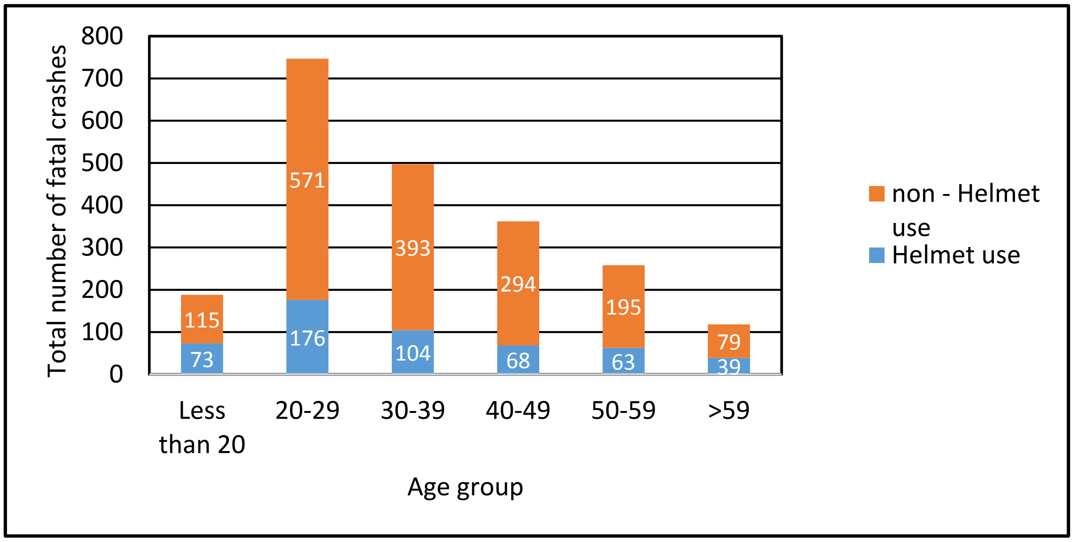


Figure 4-5: Involvement in fatal motorcycle crashes by age and helmet use (1975-2015)

As shown in table 4-7 and figure 4-6, the number of fatal crashes involving the helmet use by the motorcyclists with DUI is 17.9 percent whereas the number of fatal crashes involving the helmet use by the motorcyclists with DWI is 29.04 percent. The frequency distribution shows that the total number fatal crashes involving the motorcyclists with DUI is 827 whereas the total number of fatal crashes involving the motorcyclists with DWI is 1284.

Table 4-7: Percent of helmet use based on alcohol consumption (1975-2015)

Alcohol Consumption	Total Fatal Crashes	Helmet Use	Percent of Helmet Use
DUI	827	148	17.89%
DWI	1284	373	29.05%

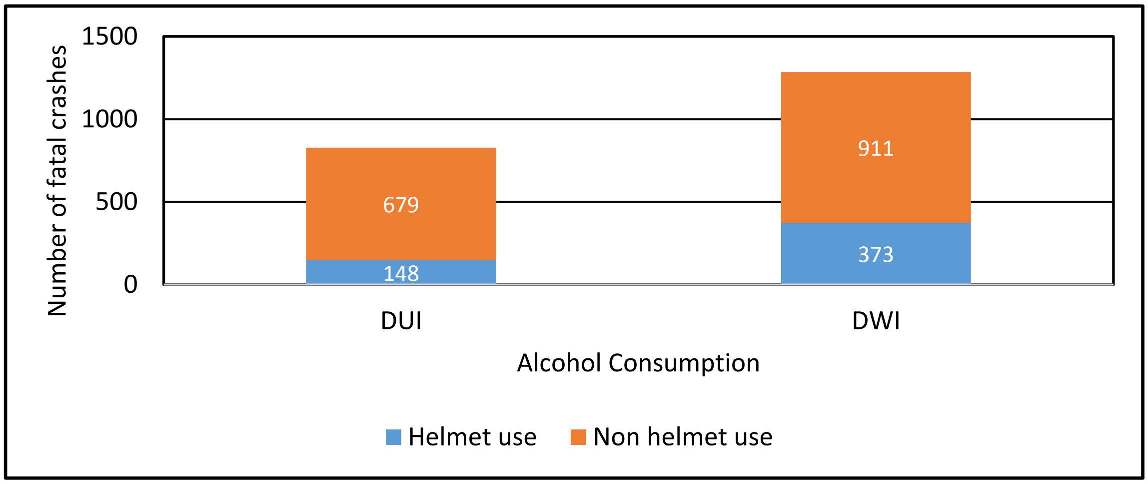


Figure 4-6: Involvement in fatal crashes by alcohol consumption and helmet use (1975-2015)

As shown in table 4-8 and figure 4-7, the total number of fatal crash for the motorcyclist during the night is 981 where as the motorcycles crashes during the day is 1112. The percentage of motorcycle crashes involving the use of helmet during the night is 26.4 whereas the percentage of motorcycle crashes involving the use of helmet during the day is 23.8.

Table 4-8: Percent of helmet use based on time of day

Time of Day	Total Fatal Crashes	Helmet Use	Percent Helmet Use
Day	1112	265	23.83%
Night	981	259	26.40%

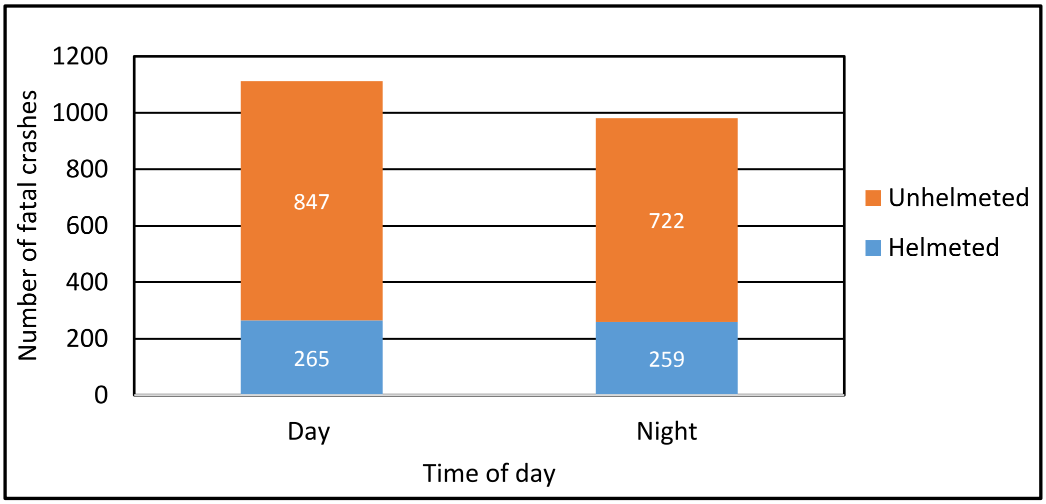


Figure 4-7: Involvement in fatal crash by time of day and helmet use (1975-2015)

4.3. Results for the frequency table and percentages of total motorcycle crashes in South Carolina (2013-2015)

As shown in table 4-9, the unhelmeted motorcyclists are higher than the helmeted motorcyclists. The number of the motorcyclists with blood alcohol level higher than 0.08 percent are more involved in unhelmeted motorcycle crashes. The average age of the motorcycle riders involving in the crashes is 40. The table also shows that the White people are more involved in the motorcycle crashes than the people of other race. The injury crashes are higher with all level of severity for the unhelmeted motorcycle riders.

Table 4-9: Frequency table of total motorcycle crashes in South Carolina (2013-2015)

Motorcycle riders Involved in total motorcycle crashes in SC (2013-2015)					
		Total	Helmeted	Unhelmeted	Unknown
Total		7947	2716	4471	760
BAC >0.08(fatal crash)		97	16	79	2
Too fast (ESC>SPL)		1309	354	876	79
Average Age		39.83	38.97	40.33	40.34
Race	Black	1744	`519	1099	126
	White	5828	2118	3272	438
	Other	375	79	100	196
Severity level	Fatal Injury	355	93	253	9
	Incapacitating injury	1221	317	845	59
	Non-Incapacitating injury	2275	782	1359	134
	Minor injury	1800	731	928	141
	No injury	2204	793	1086	325

Table 4-10: Percentages of total motorcycle riders involved in the total motorcycle crashes (2013-1015)

Motorcycle riders Involved in total motorcycle crashes in SC (2013-2015)					
		Total	Helmeted	Unhelmeted	Unknown
Total		100%	34.18%	56.26%	9.56%
BAC >0.08(fatal crash)		100%	16.4%	81.44%	2.06%
Too fast (ESC>SPL)		100%	27.04%	66.92%	6.03%
Average Age		39.83	38.97	40.33	40.34
Race	Black	21.95%	6.53%	13.83%	1.59%
	White	73.34%	26.65%	41.17%	5.51%
	Other	4.72%	0.99%	1.26%	2.47%
Severity level	Fatal Injury	4.47%	1.17%	3.18%	0.11%
	Incapacitating injury	15.36%	3.99%	10.63%	0.74%
	Non-Incapacitating injury	28.63%	9.84%	17.10%	1.69%
	Minor injury	22.65%	9.20%	11.68%	1.77%
	No injury	27.73%	9.98%	13.67%	4.09%

4.4. Cost-Benefit Analysis

The total lives saved using helmets in South Carolina from 1980 to 2015 is 240 and the additional lives that could have been saved by 100 percent use of helmet is 587. The total economic costs saved by the used of helmet in South Carolina from 1980 to 2015 is 1.79 billion and the additional costs that could have been saved if the helmet use was 100 percent is 4.1 billion as shown in table 4-11

Table 4-11: Lives and costs saved by the helmet use

From 1980-2015 (South Carolina)	
Actual lives saved by voluntary helmet use in SC	240
Additional lives that could have been saved with 100% helmet use	587
Economic cost savings from actual helmet use	$1.79 billion
Additional cost that could have been saved with 100% helmet use	$4.1 billion

4.5. Results for the Logistic Regression

The analysis in table 4-12 shows that crash-associated factors such as drunk status, age and helmet law, are significant contributors to the helmet usage in motorcycle crashes. It remains to assess their relative influence as well as estimate the amount of risk each carried (odds ratio) in the helmet usage of motorcycle riders. The gender looks insignificant as the number of samples for the crashes involving females is very less.

Table 4-12: Logistic Regression Predicting Motorcycle Helmet Use in Fatal Crashes, 1975-2015

Coefficient	Estimate	Standard Error	Z-value	P-value
Intercept	-0.5508	0.3378	-1.631	0.102979
Alcohol Consumption	-0.3331	0.1097	-3.036	0.0024
Age Group(20-29 vs <20)	-0.573	0.172	-3.331	0.000865
Age Group (30-39 vs <20)	-0.6372	0.1862	-3.421	0.000623
Age Group (40-49 vs <20)	-0.7409	0.2063	-3.592	0.000329
Age Group (50-59 vs <20)	-0.2049	0.2097	-0.977	0.328502
Age Group (>59 vs <20)	0.1951	0.2653	0.735	0.462081
Male vs Female	-0.3028	0.3069	-0.987	0.323724
Helmet Law vs No Helmet Law	2.3725	0.1833	12.942	<2e-16
Day vs Night	0.1221	0.1136	1.075	0.282198

The odds ratio in table 4-13 shows the odds of the motorcyclist using the helmet in a fatal crash in a category to the odds of the motorcyclist using the helmet in the associated reference category. The results for the logistic regression analysis are as follows:

4.3.1. Alcohol Consumption

The odds ratio of likelihood of motorcycle helmet use indicate that regarding the motorcyclist with DUI (Driving Under Influence), the motorcyclists with DWI (Driving Without Influence) are more likely to wear the helmets with the odds ratio of 0.309. This shows that the motorcyclists with DUI is 30.9 percent less likely to wear the helmet than motorcyclists with DWI.

4.3.2. Age Group

The odds ratio for the age group 20-29 with respect to the age group less than 20 is 0.566. The likelihood of motorcyclist with age group 20-29 is 43.4 percent less than the age group less than 20.

The odds ratio for the age group 30-39 with respect to the age group less than 20 is 0.5308 which mean that the motorcyclists with age group 30-39 is 46.92 percent less likely to wear the helmet than the motorcyclist with age group less than 20.

The odds ratio for the age group 40-49 with respect to the age group less than 20 is 0.489. The motorcyclists with age group 40-49 is 51.1 percent less likely to wear the helmet than the motorcyclist with age group less than 20.

The odds ratio for the age group 50-59 with respect to the age group less than 20 is 0.831. The likelihood of motorcyclists with age group 50-59 is 16.9 percent less than the age group less than 20.

The odds ratio for the age group greater than 59 (Age group >59) with respect to the age group less than 20 (age group <20) is 1.25 which means age group greater than 59 is more likely to wear the helmet than the age group less than 20.

4.3.3. Helmet Law

Motorcyclists are more likely to wear the helmets during the Universal Helmet Law compared to the years with Non – Universal Helmet Law. Table-1 shows that the odds ratio of using the helmet by the motorcyclists during the Universal Helmet Law is 10.61 times more than compared to the Non – Universal Helmet Law.

Table 4-13: Logistic Regression predicting the odds ratio of helmet use in fatal crashes, 1975-2015

Parameter	**Level**	**Odds ratio**	**95% confidence interval of the odds ratio**	
Alcohol Consumption	DUI vs DWI	0.69	0.559	0.848
Age Group	20-29 vs less than 20	0.566	0.404	0.794
	(30-39 vs <20)	0.53	0.368	0.765
	(40-49 vs <20)	0.488	0.326	0.729
	(50-59 vs <20)	0.831	0.55	1.25
	(>59 vs <20)	1.254	0.742	2.09
Helmet Law	Universal Helmet Law vs No Universal Helmet Law	10.61	7.46	15.32

4.4. Results for the Block Spatial Join

There are more blocks in South Carolina with the crashes less than 50% helmeted motorcyclists. The blocks with lower average income are more involved in the crashes with greater than 50% helmeted motorcyclists. The percentage of population with higher college degree is higher for the blocks with the crashes greater than 50% helmeted motorcyclists.

Table 4-14: Assignment of blocks to helmeted and unhelmeted groups

Socio Economic Statistics	**Greater than 50% of Crash-Involved Motorcyclists were Helmeted**	**Less than 50% of Crash-Involved Motorcyclists were Unhelmeted**	**No Motorcyclists involved in crashes**
Number of block groups	750	1629	675
Total population	1226915	2707376	691073
Average household income	47190	43505	43176
% of population with college degree or higher	22.15	19.6	23
% of population with High school Diploma	32.18	33.73	29.7
Percent of population in poverty	15.57	17.63	20.78
Vehicle per household	1.79	1.76	1.54

4.5. Discussion of Results of Buffer Analysis

The map below shows the classification of functional class roads based on the number of crashes. The line weight determines the type of functional class and the type of color identifies the number of crashes. Red color indicates the number of crashes greater than 15, orange color indicates the crashes from 10 to 15, blue color indicates the crashes from 5 to 10 and green color indicates the crashes from 0 to 5.

The figure 4-8 as shown below indicates that greater than fifteen crashes have occurred in the Principal arterial freeways, minor arterial and local roads. The number of motorcycle crashes from 10-15 also occurs principal arterial freeways, minor arterial, major collector and the local roads where as the Principal arterial interstates have the crashes ranging from 0 to 5 and 5 to 10.

Since major number of crashes have occurred in the freeways, minor arterial and local roads so more attention or safety measures should be given to such roadways regarding the motorcycle crashes.

The routes, which are prone to higher crashes, are Cleo Chapman Highway, Highway 17, Kings Highway, and Ashville Highway. The segment of the highway with higher crashes passes through the urban areas. Higher number of crashes in local roads have occurred around the Columbia city. The local roads are like Laurel Road, Cedar Road and Maple Road. The local roads around the Greenville city with higher number of crashes are Watson Road, Lee Road, Taylor Road, Greek Road.

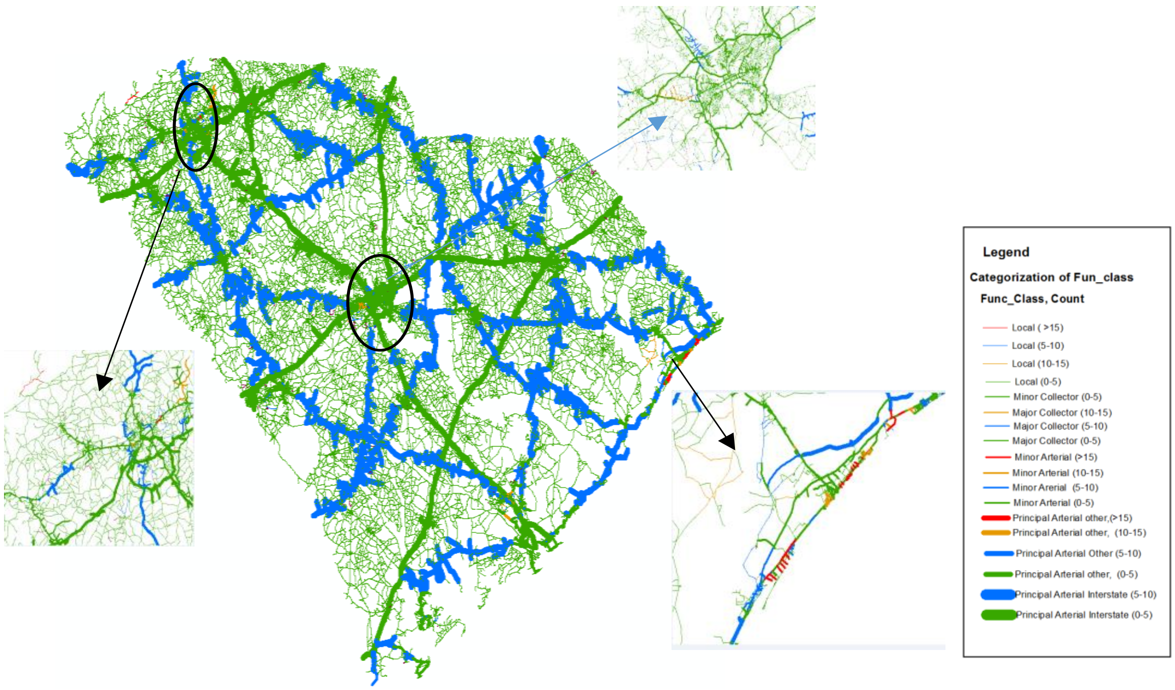


Figure 4-7: Color thematic map showing the classification of roadways based on functional class and number of crashes

4.6. Results for the Hot Spot Analysis without normalization

The hotspot analysis performed using the kernel density estimation shows that the red spots are the places with the high number of fatal crashes and which needs the further investigation for the implementing the safety measures whereas the blue spots shows the areas with the less number of fatal crashes. The Kernel density estimation evaluates the density of the area. The figure 4-8 shown below indicates that the urban areas are more prone to the accident than the rural areas. The red spots are mostly towards the Greenville, Columbia, Charleston and the Myrtle beach area.

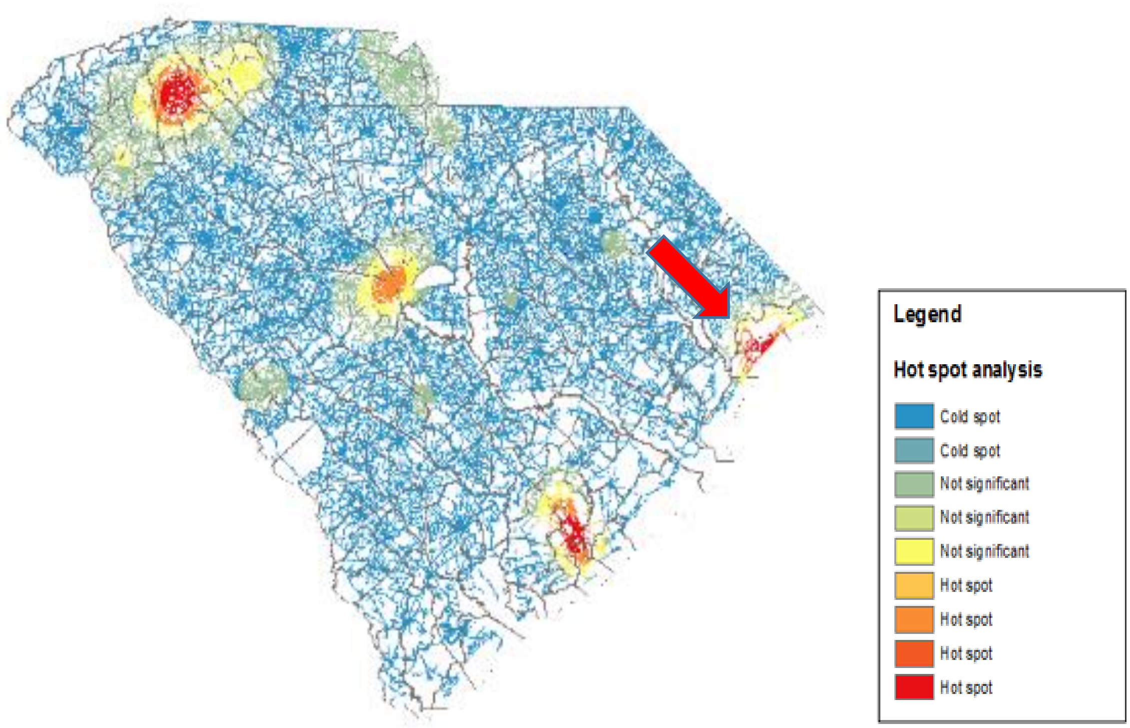


Figure 4-8: Hot spot analysis using Kernel Density Estimation Method

4.7. Results for Kriging Analysis of total motorcycles normalized by population

The result for the hot spot analysis of total motorcycle crashes using the Kriging method showed that higher number of crashes are basically towards the Myrtle beach area and the mountainous area in the Anderson part. When the crashes are normalized with the population, Charleston, which was a hot spot during the KDE analysis changes to Cold spot. Although the population of the Myrtle beach area is low the analysis shows the higher number of crashes in those areas. The crashes may be higher in those places as bikers tend to ride more in the mountainous areas and because of the bike rally that happens every year in Myrtle beach area.

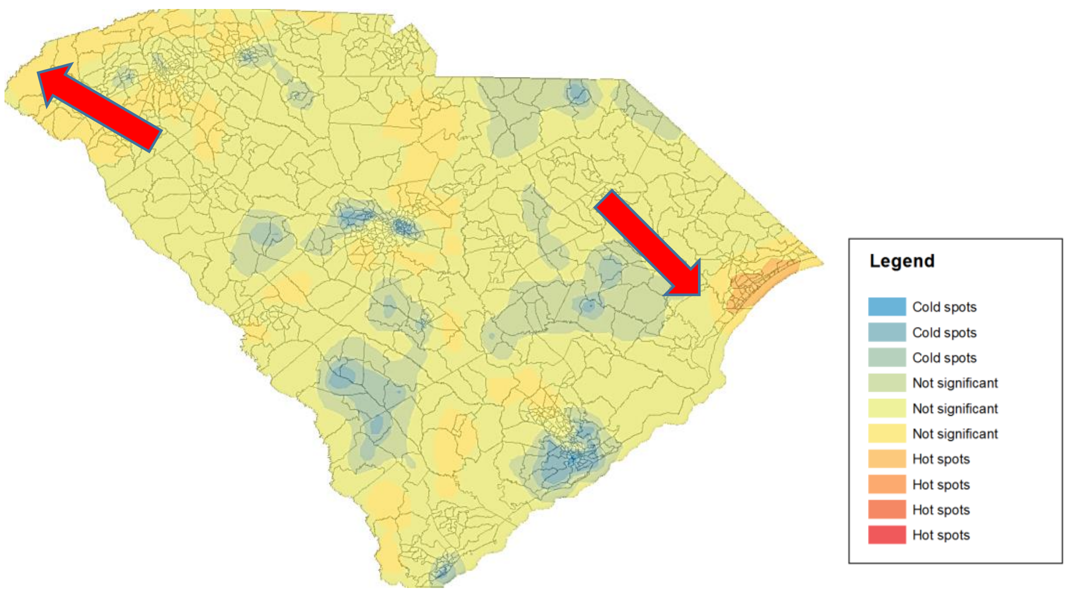


Figure 4-9: Kriging analysis of total motorcycle crashes normalized by population

4.8. Results for the Word Cloud of the Opponent Viewpoints

As shown in figure 4-10 the opponents viewpoints mostly focused on their choice, freedom, personal thoughts, opinions and personal safety instead of public safety.

Figure 4-10: Word Cloud of the Opponents Viewpoints

4.9. Results for Opponents Viewpoints and Counter message

Various opponents' viewpoints were analyzed through the word cloud and counter message for those viewpoints were given.

"My dad said I look stupid wearing a motorcycle helmet on my scooter. Going to take advantage of the no helmet laws here in Michigan. For dad!" (*Source: Twitter)*

- States needs the motorcycle helmet laws. Billions of public dollars are saved using the helmets.
- Wearing a motorcycle helmet may make you look stupid but not wearing a motorcycle helmet makes you stupid.

"free country. I still don't think motorcycle helmet laws are needed or the war on smoking (pot excepted)" (*Source: NHTSA*)

- Motorcycle helmets reduce the deaths by 37% and the injury by 69% (*Source: NHTSA*)
- The estimated costs of the crashes in 2015 including medical cost, productivity cost and the property damage was almost $152 billion. (*Source: NHTSA)*
- The economic costs that can be saved using helmet use is $4 billion and the comprehensive cost that can be saved by the helmet use is $25 billion. (*Source: NHTSA*)

4.10. Results for the word cloud of the Proponents viewpoints

The proponents' viewpoints mostly focused on the facts and researches that are being done which shows that helmet is effective in saving the lives of people. Their viewpoints are mainly centered on the hospitals costs, injuries, accidents that are increasing due to lack of Universal Helmet Law. They are more concerned towards the Public safety than the personal safety and choice.

Figure 4-11: Word cloud of proponent's viewpoints

4.11. Results for the Proponents viewpoints and supporting facts

Various proponents' viewpoints were analyzed through the word cloud and supporting facts for those viewpoints were given.

"Motorcycle riders' injuries differ with helmet use"

- Helmeted motorcyclists are less likely to hurt their head and the other body parts. (*Source: NHTSA*)
- Helmeted motorcyclists were significantly less likely to experience a traumatic brain injury (*Source: NHTSA*)
- Helmeted motorcyclists are less likely to get high severity level injuries than unhelmeted motorcyclists are so they are more likely to survive. (*Source: NHTSA*)

- Motorcyclists with TBI were much less likely to be discharged home and more likely to require rehabilitation or to be discharged to a long-term care facility following their hospitalization (*Source: NHTSA*)

CHAPTER 5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

For objective 1: Evaluate the impacts after the repeal of the Universal Helmet Law on the motorcycle crashes, injuries and fatalities in South Carolina

- From 1980 to 2015 helmets saved the lives of more than 200 people and additional lives of 587 could have been saved if the helmet use was 100 percent
- From 1980 to 2015, the economic costs saved by the state using helmet is \$1.79 billion and additional costs of \$4.1 billion could have been saved if the helmet use was 100%
- The percentage of wearing the helmet before the repeal of helmet law is more than three times the percentage of wearing the helmet after the repeal of the helmet law.

For objective 2: Identify the Behavioral/ Socio- demographic/ Socio-economic/Geographic factors associated motorcycle crashes in South Carolina

- The average age of the motorcyclists in the total motorcycle crashes (2013-2015) is 40 that is most of the motorcyclists involving in the crashes are younger age people.

- The involvement of White race people in the total motorcycle crash is higher than the other race.
- Higher household income and education attainment increases the rate of helmet use
- There are significantly higher number of blocks in South Carolina with lower rate of helmet use (<50%)
- More people from the helmeted block group would potentially go to get the higher degree
- Urban areas are the primary hot spots for the total number of motorcycle crashes (2010-2015) which is due to the population of those areas
- Hot spot analysis of normalized crashes with population showed some remarkable difference from the non – normalized crashes
- Bikers ride more in the mountainous areas and bike rallies in the Myrtle beach area is also one of the major cause of higher number of crashes even though the population is less (normalized for population)
- Higher number of crashes are in the freeways, minor arterial and local roads

- Highways like Cleo Chapman Highway, Highway 17, Kings Highway, Ashville Highway are prone to motorcycle crashes
- Local roads around the Columbia City like laurel road, cedar road, Maple road consists of higher motorcycle crashes.

For objective 3: Characterize the opponent/ advocate viewpoints on Universal Helmet Laws to enable the development of persuasive educational materials

- The opponents view mostly focused on their personal choice and freedom instead of the public safety
- The proponents' views focused on the public safety, effectiveness of Universal helmet laws, injuries and cost that have increased due to the lack of helmet law
- The proponents' views are basically based on the facts and researches than their opinion

5.2. Recommendations

The following are the recommendations, which can be implemented further for the improvement of the motorcycle safety in South Carolina

- Encourage the state of South Carolina to reinstate the Universal Helmet Law

- Educate riders on effectiveness of helmets
- Target pro-helmet messages to younger rider population
- Motorcycle training/helmet use requirements for licensing
- Develop targeted enforcement in hot spots
- Develop targeted messaging specifically focusing on counteracting the opponent viewpoints.
- Free helmets can be provided to encourage motorcyclists to wear the helmets.
- The cost per fatality for 2015 is $ 9.5 million. If that cost is saved, then the number of helmets that can be bought is 9500.

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APPENDICES

APPENDIX A:

MOTORCYCLE REGISTRATION, NUMBER OF FATAL CRASHES, FATALITIES IN SOUTH CAROLINA (1975-2015)

Years	Total number of registered motorcycles	Total number. Of fatal crashes for motorcycles (K)	Total number of fatalities in motorcycle crash
1975	40926	29	30
1976	45801	29	30
1977	41293	33	34
1978	35411	23	23
1979	37450	28	30
1980	38994	38	39
1981	42402	29	29
1982	39168	45	46
1983	36284	42	47
1984	37264	64	67
1985	37524	52	55
1986	36234	43	45
1987	32867	41	42
1988	31653	40	40
1989	30140	29	31
1990	31087	38	39
1991	29406	29	30
1992	32595	32	34
1993	33620	37	38
1994	34123	37	37
1995	34570	32	33
1996	39219	33	35
1997	39853	50	51

1998	41116	54	56
1999	46844	49	50
2000	51679	56	57
2001	56660	62	63

(CONTINUED)

2002	62726	64	67
2003	57177	52	54
2004	60029	64	68
2005	63022	64	68
2006	87774	82	83
2007	95011	90	93
2008	103051	83	90
2009	106263	71	71
2010	106999	59	61
2011	108371	79	81
2012	112239	83	85
2013	113315	81	87
2014	114666	60	61
2015	116241	98	100

APPENDIX B:

TOTAL NUMBER OF HELMETED AND NON-HELMETED FATAL CRASHES IN SOUTH CAROLINA (1975-2015)

Years	Total number of helmeted crashes	Total number of unhelmeted crashes
1975	25	4
1976	24	5
1977	29	4
1978	19	4
1979	18	10
1980	16	22
1981	8	21
1982	14	31
1983	10	32
1984	2	62
1985	0	52
1986	7	36
1987	8	33
1988	8	32
1989	4	25
1990	8	30
1991	0	29
1992	3	29
1993	3	34
1994	4	33
1995	6	26
1996	10	23
1997	6	44
1998	7	47

1999	18	31
2000	9	47

(CONTINUED)

2001	11	51
2002	10	54
2003	9	43
2004	16	48
2005	16	48
2006	17	65
2007	17	73
2008	22	61
2009	16	55
2010	17	42
2011	17	62
2012	29	54
2013	21	60
2014	14	46
2015	27	71

APPENDIX C:

TOTAL NUMBER OF HELMETED AND UNHELMETED CRASHES IN SOUTH CAROLINA BY AGE (1975-2015)

Years	less than 20		20-29		30-39		40-49		50-59		>59	
	Helmeted	Non-helmeted	Helmeted	Non-helmeted	Helmeted	Non-helmeted	Helmeted	Non-helmeted	Helmeted	Non-helmeted	Helmeted	Non-helmeted
1975	8	1	11	1	5	2	0	0	0	0	1	0
1976	5	1	9	2	5	1	5	0	0	0	0	1
1977	6	0	16	2	6	1	0	0	1	0	0	1
1978	2	2	9	2	2	0	4	0	2	0	0	0
1979	5	2	8	4	1	2	2	1	2	1	1	0
1980	3	2	8	16	5	6	0	2	0	0	0	0
1981	0	2	3	15	4	3	1	1	0	0	0	0
1982	7	2	3	16	4	8	0	3	0	2	0	0
1983	2	6	7	20	0	5	1	1	0	0	0	0
1984	1	17	1	27	0	11	0	6	0	1	0	0
1985	0	7	0	27	0	13	0	3	0	2	0	0
1986	3	8	3	20	1	5	0	2	0	0	0	1
1987	4	3	3	19	1	7	0	3	0	1	0	0
1988	1	8	4	16	1	8	2	0	0	0	0	1
1989	1	0	1	14	2	6	0	3	0	2	0	0
1990	1	4	3	16	2	6	2	3	0	1	0	0
1991	0	6	0	11	0	8	0	4	0	0	0	0

1992	0	4	0	14	2	7	0	3	1	1	0	0
1993	0	4	1	20	0	5	0	5	2	0	0	0
1994	1	7	3	19	0	4	0	2	0	2	0	0
1995	1	2	5	10	0	10	0	3	0	1	0	0
1996	0	3	7	7	2	5	1	7	0	0	0	1
1997	0	0	1	16	1	13	3	7	1	8	0	0
1998	1	3	3	45	2	16	1	9	0	4	0	1
1999	0	3	7	13	4	11	3	6	0	1	1	0
2000	0	2	5	16	1	16	1	7	2	6	0	0
2001	1	1	3	16	3	12	1	12	2	9	1	1
2002	0	2	3	16	3	15	4	14	0	7	0	1
2003	0	1	0	11	3	15	0	5	5	8	1	5
2004	1	0	4	14	3	15	1	17	1	9	3	5
2005	2	0	4	7	5	11	4	15	1	11	1	4
2006	1	1	2	14	4	17	3	19	6	11	1	5
2007	2	0	5	13	2	16	1	25	5	15	2	5
2008	2	4	5	16	6	11	3	21	4	9	3	4
2009	3	0	2	8	2	15	5	18	2	10	2	6
2010	1	0	7	9	3	14	1	6	2	10	3	3
2011	2	2	3	15	0	13	8	15	1	10	3	7
2012	2	2	4	8	5	19	3	11	8	11	7	4
2013	1	1	5	12	4	15	3	13	4	15	4	5
2014	2	1	0	6	4	10	2	9	3	11	3	10
2015	1	1	8	18	6	16	3	13	8	16	2	8

APPENDIX D:

TOTAL NUMBER OF HELMETED AND UNHELMETED FATAL CRASHES IN SOUTH CAROLINA BY GENDER (1975-2015)

Sex

Years	male		Female	
	helmeted	unhelmeted	helmeted	unhelmeted
1975	25	4	0	0
1976	29	0	0	0
1977	25	4	0	0
1978	17	4	2	0
1979	18	8	0	2
1980	16	22	0	0
1981	8	20	0	0
1982	14	30	0	1
1983	10	30	0	2
1984	2	62	0	0
1985	0	52	0	0
1986	7	36	0	0
1987	7	32	1	1
1988	8	31	0	1
1989	4	24	0	1
1990	8	29	0	1
1991	0	28	0	1
1992	3	29	0	0
1993	3	34	0	0
1994	4	31	0	2
1995	6	24	0	2
1996	9	21	1	2
1997	6	44	0	0
1998	7	46	0	1
1999	18	30	0	1
2000	9	45	0	2

(CONTINUED)

2001	11	51	0	0
2002	10	53	0	1
2003	8	42	1	1
2004	12	57	0	0
2005	14	46	2	2
2006	16	62	1	3
2007	16	72	1	1
2008	22	57	0	4
2009	14	53	2	2
2010	17	41	0	1
2011	17	61	0	1
2012	29	53	0	1
2013	21	59	0	1
2014	14	45	0	1
2015	22	68	5	3

APPENDIX E:

TOTAL NUMBER OF HELMETED AND UNHELMETED FATAL CRASHES IN SOUTH CAROLINA BY ALCOHOL CONSUMPTIONS (1975-2015)

Years	Alcohol Consumption			
	helmeted	unhelmeted	helmeted	unhelmeted
	DUI		DWI	
1975	6	2	19	2
1976	0	0	24	5
1977	8	0	21	0
1978	10	2	9	2
1979	6	2	12	8
1980	2	11	14	11
1981	2	9	6	12
1982	4	15	10	16
1983	3	12	7	20
1984	0	27	2	35
1985	0	26	0	26
1986	1	12	6	24
1987	2	14	6	19
1988	4	8	4	24
1989	1	9	3	16
1990	4	12	4	18
1991	0	10	0	19
1992	0	13	3	16
1993	0	10	3	24
1994	0	9	4	24
1995	2	6	4	24
1996	7	10	3	13
1997	0	12	6	32
1998	1	12	6	35
1999	4	7	14	24
2000	1	13	8	34

(CONTINUED)

2001	4	30	7	21
2002	3	30	7	24
2003	0	22	9	21
2004	3	22	9	35
2005	5	26	11	22
2006	4	28	13	37
2007	6	32	11	41
2008	6	36	16	25
2009	6	25	10	30
2010	6	27	11	15
2011	10	33	7	29
2012	11	26	18	28
2013	5	29	16	31
2014	6	22	8	26
2015	5	28	22	43

APPENDIX F:

TOTAL NUMBER OF HELMETED AND UNHELMETED FATAL CRASHES IN SOUTH CAROLINA BY TIME OF DAY (1975-2015)

Years	Time of day			
	helmeted	unhelmeted	helmeted	unhelmeted
	Night		Day	
1975	16	0	12	1
1976	12	0	12	5
1977	22	2	7	2
1978	14	3	5	1
1979	8	8	10	2
1980	9	10	7	9
1981	3	13	5	8
1982	10	21	4	9
1983	5	15	5	17
1984	1	39	1	23
1985	0	29	0	23
1986	5	21	2	15
1987	4	17	4	16
1988	5	17	3	15
1989	3	12	1	13
1990	3	20	5	10
1991	0	22	0	7
1992	2	16	1	13
1993	0	18	3	16
1994	2	21	2	12
1995	3	15	3	11
1996	4	11	6	12
1997	4	24	2	20
1998	2	23	5	24
1999	8	14	10	17
2000	4	22	5	24

(CONTINUED)

2001	4	31	7	19
2002	7	32	3	22
2003	5	24	4	19
2004	6	28	6	29
2005	5	21	11	27
2006	7	28	10	27
2007	5	44	12	29
2008	12	24	10	37
2009	6	31	10	24
2010	7	19	10	23
2011	11	31	6	31
2012	13	25	16	29
2013	8	33	13	27
2014	8	23	6	23
2015	12	40	15	31

Appendix G:

R code for the Logistic Regression

R code for Logistic Regression

```
data=read.csv(file.choose())

names(data)

m1=glm(MAN_REST~DRUNK_DR+Age.Group.20.29+Age.Group.30.39+Age.Group
.40.49+Age.Group.50.59+Age.Group.60+SEX+Helmet.Law+LGT_cond,family="bin
omial", data=data)

summary(m1)

data=read.csv(file.choose())

names(data)

m2=glm(MAN_REST~DRUNK_DR+Age.Group.20.29+Age.Group.30.39+Age.Group
.40.49+Age.Group.50.59+Age.Group.60+Helmet.Law, family="binomial",
data=data)

summary(m2)

exp(cbind(coef(m2), confint(m2)))
```

Appendix H:

Lives and costs saved by the helmet (1975-2015)

Year	Total number of fatalities	Total number of helmeted fatalities	Total number of Non - helmeted fatalities	Fatalities potential	Number of lives saved by helmets	additional preventable fatalities at 100-percent helmet use	Annual	Inflation factor	Cost per fatality	cost saving by helmet use	Cost savings for fatalities by 100 percent helmet use
1975	30	26	4	41.27	15.27	1.48	53.80	0.23	2156385.4	32927663	3191450.402
1976	30	25	5	39.68	14.68	1.85	56.90	0.24	2280638.1	33485559	4219180.481
1977	34	30	4	47.62	17.62	1.48	60.60	0.26	2428939.7	42795604	3594830.751
1978	23	19	4	30.16	11.16	1.48	65.20	0.28	2613314.7	29161273	3867705.692
1979	30	20	10	31.75	11.75	3.70	72.60	0.31	2909917.9	34179987	10766696.06
1980	39	16	23	25.40	9.40	8.51	82.40	0.35	3302716.7	31035052	28106118.97
1981	29	8	21	12.70	4.70	7.77	90.90	0.38	3643409.5	17118242	28309292.16
1982	46	14	32	22.22	8.22	11.84	96.50	0.41	3867866	31802454	45795533.65
1983	47	10	37	15.87	5.87	13.69	99.60	0.42	3992118.7	23445777	54652105.12
1984	67	2	65	3.17	1.17	24.05	103.90	0.44	4164469.2	4891598.8	100155484.6
1985	55	0	55	0.00	0.00	20.35	107.60	0.45	4312770.8	0	87764886.06
1986	45	7	38	11.11	4.11	14.06	109.60	0.46	4392933.8	18059839	61764649.79
1987	42	8	34	12.70	4.70	12.58	113.60	0.48	4553259.9	21393094	57280009.45
1988	40	8	32	12.70	4.70	11.84	118.30	0.50	4741643	22278196	56141053.17
1989	31	4	27	6.35	2.35	9.99	124.00	0.52	4970107.6	11675808	49651375.22
1990	39	8	31	12.70	4.70	11.47	130.70	0.55	5238653.8	24613357	60087358.71
1991	30	0	30	0.00	0.00	11.10	136.20	0.57	5459102.1	0	60596033.2
1992	34	3	31	4.76	1.76	11.47	140.30	0.59	5623436.3	9907959.2	64500814.29
1993	38	3	35	4.76	1.76	12.95	144.50	0.61	5791778.6	10204562	75003533.5

1994	37	4	33	6.35	2.35	12.21	148.2	0.63	5940080	13954474	72528379.82
1995	33	6	27	9.52	3.52	9.99	152.4	0.64	6108423	21524918	61023141.8
1996	35	10	25	15.87	5.87	9.25	156.9	0.66	6288789	36934160	58171302.06
1997	51	6	45	9.52	3.52	16.65	160.5	0.68	6433083	22668959	107110829.6
1998	56	7	49	11.11	4.11	18.13	163	0.69	6533287	26859067	118448486.8
1999	50	19	31	30.16	11.16	11.47	166.6	0.7	6677580	74513314	76591843.62
2000	57	10	47	15.87	5.87	17.39	172.2	0.73	6902037	40535770	120026415.8
2001	63	11	52	17.46	6.46	19.24	177.1	0.75	7098436	45858150	136573908.2
2002	67	11	56	17.46	6.46	20.72	179.9	0.76	7210664	46583180	149404962.5
2003	54	10	44	15.87	5.87	16.28	184	0.78	7374998	43313483	120064974.2
2004	68	18	50	28.57	10.57	18.5	188.9	0.8	7571398	80040491	140070859.9
2005	68	18	50	28.57	10.57	18.5	195.3	0.82	7827920	82752292	144816511.1
2006	83	17	66	26.98	9.98	24.42	201.6	0.85	8080433	80676070	197324175.1
2007	93	18	75	28.57	10.57	27.75	207.34	0.87	8310581	87854714	230618625.5
2008	90	24	66	38.1	14.1	24.42	215.3	0.91	8629670	121637254	210736542
2009	71	16	55	25.4	9.4	20.35	214.54	0.91	8598968	80802997	174988990.3
2010	61	17	44	26.98	9.98	16.28	218.06	0.92	8740014	87261414	142287434.9
2011	81	17	64	26.98	9.98	23.68	224.94	0.95	9015896	90015845	213496405.1
2012	85	29	56	46.03	17.03	20.72	229.59	0.97	9202475	156734216	190675280.5
2013	87	23	64	36.51	13.51	23.68	232.96	0.98	9337269	126127238	221106531.3
2014	61	14	47	22.22	8.22	17.39	236.74	1	9488737	78018505	165009138.1
2015	100	28	72	44.44	16.44	26.64	237.02	1	9500000	156222222	253080000